Studies in Mycology 101: 287–415 (2022).

Species diversity, systematic revision and molecular phylogeny of *Ganodermataceae* (*Polyporales*, *Basidiomycota*) with an emphasis on Chinese collections

Y.-F. Sun[1#], J.-H. Xing[1#], X.-L. He[2], D.-M. Wu[3], C.-G. Song[1], S. Liu[1], J. Vlasák[4], G. Gates[5], T.B. Gibertoni[6], B.-K. Cui[1*]

[1]*Institute of Microbiology, School of Ecology and Nature Conservation, Beijing Forestry University, Beijing 100083, China;* [2]*Sichuan Institute of Edible Fungi, Sichuan Academy of Agricultural Sciences, Chengdu, Sichuan 610066, China;* [3]*Biotechnology Research Institute, Xinjiang Academy of Agricultural and Reclamation Sciences / Xinjiang Production and Construction Group Key Laboratory of Crop Germplasm Enhancement and Gene Resources Utilization, Shihezi, Xinjiang 832000, China;* [4]*Biology Centre, Czech Academy of Sciences, Institute of Plant "Molecular Biology, Branišovská 31, CZ-370 05 České Budějovice, Czech Republic;* [5]*Tasmanian Institute of Agriculture, Private Bag 98, Hobart, Tasmania 7001, Australia;* [6]*Universidade Federal de Pernambuco, Centro de Biociências, Departamento de Micologia, Av. Avenida da Engenharia, s/n, CEP 50740-600, Recife, Pernambuco, Brasil*

[#]These authors contributed equally to the work
**Corresponding author*: Bao-Kai Cui, cuibaokai@bjfu.edu.cn, baokaicui2013@gmail.com

Abstract: *Ganodermataceae* is one of the main families of macrofungi since species in the family are both ecologically and economically important. The double-walled basidiospores with ornamented endospore walls are the characteristic features of *Ganodermataceae*. It is a large and complex family; although many studies have focused on *Ganodermataceae*, the global diversity, geographic distribution, taxonomy and molecular phylogeny of *Ganodermataceae* still remained incompletely understood. In this work, taxonomic and phylogenetic studies on worldwide species of *Ganodermataceae* were carried out by morphological examination and molecular phylogenetic analyses inferred from six gene loci including the internal transcribed spacer regions (ITS), the large subunit of nuclear ribosomal RNA gene (nLSU), the second largest subunit of RNA polymerase II gene (*rpb2*), the translation elongation factor 1-α gene (*tef1*), the small subunit mitochondrial rRNA gene (mtSSU) and the small subunit nuclear ribosomal RNA gene (nSSU). A total of 1 382 sequences were used in the phylogenetic analyses, of which 817 were newly generated, including 132 sequences of ITS, 139 sequences of nLSU, 83 sequences of *rpb2*, 124 sequences of *tef1*, 150 sequences of mtSSU and 189 sequences of nSSU. The combined six-gene dataset included sequences from 391 specimens representing 146 taxa from *Ganodermataceae*. Based on morphological and phylogenetic analyses, 14 genera were confirmed in *Ganodermataceae*: *Amauroderma*, *Amaurodermellus*, *Cristataspora*, *Foraminispora*, *Furtadoella*, *Ganoderma*, *Haddowia*, *Humphreya*, *Magoderna*, *Neoganoderma*, *Sanguinoderma*, *Sinoganoderma*, *Tomophagus* and *Trachydermella*. Among these genera, *Neoganoderma gen. nov.* is proposed for *Ganoderma neurosporum*; *Sinoganoderma gen. nov.* is proposed for *Ganoderma shandongense*; *Furtadoella gen. nov.* is proposed to include taxa previously belonging to *Furtadoa* since *Furtadoa* is a homonym of a plant genus in the *Araceae*; *Trachydermella gen. nov.* is proposed to include *Trachyderma tsunodae* since *Trachyderma* is a homonym of a lichen genus in the *Pannariaceae*. Twenty-three new species, *viz*., *Ganoderma acaciicola*, *G. acontextum*, *G. alpinum*, *G. bubalinomarginatum*, *G. castaneum*, *G. chuxiongense*, *G. cocoicola*, *G. fallax*, *G. guangxiense*, *G. puerense*, *G. subangustisporum*, *G. subellipsoideum*, *G. subflexipes*, *G. sublobatum*, *G. tongshanense*, *G. yunlingense*, *Haddowia macropora*, *Sanguinoderma guangdongense*, *Sa. infundibulare*, *Sa. longistipitum*, *Sa. melanocarpum*, *Sa. microsporum* and *Sa. tricolor* are described. In addition, another 33 known species are also described in detail for comparison. Scanning electron micrographs of basidiospores of 10 genera in *Ganodermataceae* are provided. A key to the accepted genera of *Ganodermataceae* and keys to the accepted species of *Ganoderma*, *Haddowia*, *Humphreya*, *Magoderna*, *Sanguinoderma* and *Tomophagus* are also provided. In total, 278 species are accepted as members of *Ganodermataceae* including 59 species distributed in China.

Key words: *Ganoderma*, macro fungi, medicinal mushrooms, new taxa, phylogeny, ultrastructure, white-rot fungi.
Taxonomic novelties: New genera: *Furtadoella* B.K. Cui & Y.F. Sun, *Neoganoderma* B.K. Cui & Y.F. Sun, *Sinoganoderma* B.K. Cui, J.H. Xing & Y.F. Sun and *Trachydermella* B.K. Cui & Y.F. Sun; **New species:** *Ganoderma acaciicola* B.K. Cui, J.H. Xing & Y.F. Sun, *G. acontextum* B.K. Cui, J.H. Xing & Vlasák, *G. alpinum* B.K. Cui, J.H. Xing & Y.F. Sun, *G. bubalinomarginatum* B.K. Cui, J.H. Xing & Y.F. Sun, *G. castaneum* B.K. Cui, J.H. Xing & Y.F. Sun, *G. chuxiongense* B.K. Cui, J.H. Xing & Y.F. Sun, *G. cocoicola* B.K. Cui, J.H. Xing & Y.F. Sun, *G. fallax* B.K. Cui, J.H. Xing & Vlasák, *G. guangxiense* B.K. Cui, J.H. Xing & Y.F. Sun, *G. puerense* B.K. Cui, J.H. Xing & Y.F. Sun, *G. subangustisporum* B.K. Cui, J.H. Xing & Y.F. Sun, *G. subellipsoideum* B.K. Cui, J.H. Xing & Y.F. Sun, *G. subflexipes* B.K. Cui, J.H. Xing & Y.F. Sun, *G. sublobatum* B.K. Cui, J.H. Xing & Y.F. Sun, *G. tongshanense* B.K. Cui, J.H. Xing & Y.F. Sun, *G. yunlingense* B.K. Cui, J.H. Xing & Y.F. Sun, *Haddowia macropora* B.K. Cui, Vlasák & Y.F. Sun, *Sanguinoderma guangdongense* B.K. Cui & Y.F. Sun, *Sa. infundibulare* B.K. Cui & Y.F. Sun, *Sa. longistipitum* B.K. Cui & Y.F. Sun, *Sa. melanocarpum* B.K. Cui & Y.F. Sun, *Sa. microsporum* B.K. Cui & Y.F. Sun and *Sa. tricolor* B.K. Cui & Y.F. Sun; **New combinations**: *Furtadoella biseptata* (Costa-Rezende *et al.*) B.K. Cui & Y.F. Sun, *Fu. brasiliensis* (Singer) B.K. Cui & Y.F. Sun, *Fu. corneri* (Gulaid & Ryvarden) B.K. Cui & Y.F. Sun, *Neoganoderma neurosporum* (J.S. Furtado) B.K. Cui & Y.F. Sun, *Sinoganoderma shandongense* (J.D. Zhao & L.W. Xu) B.K. Cui, J.H. Xing & Y.F. Sun and *Trachydermella tsunodae* (Yasuda ex Lloyd) B.K. Cui & Y.F. Sun.

Citation: Sun Y-F, Xing J-H, He X-L, Wu D-M, Song C-G, Liu S, Vlasák J, Gates G, Gibertoni TB, Cui B-K (2022). Species diversity, systematic revision and molecular phylogeny of *Ganodermataceae* (*Polyporales*, *Basidiomycota*) with an emphasis on Chinese collections. *Studies in Mycology* **101**: 287–415. doi: 10.3114/sim.2022.101.05.
Received: 13 December 2021; **Accepted:** 6 April 2022; **Effectively published online:** 20 May 2022
Corresponding editor: Robert A. Samson

INTRODUCTION

Ganodermataceae as an important family in the *Polyporales* has been researched for many decades due to its high medicinal and ecological values. As traditional medicine, *Ganoderma lingzhi*, *G. sinense* and *Amauroderma rugosum* have been used for anti-cancer treatment, for lowering blood pressure and for improving immunity (Dai *et al.* 2009, Cao *et al.* 2012, Chan *et al.* 2013, Zhou *et al.* 2015, Zhang *et al.* 2019). Tree pathogens such as *G. boninense* can cause a basal stem rot on oil palm trees (Pilotti 2005), and *G. philippii* can cause a red root rot on *Acacia mangium* (Glen *et al.* 2009). Besides, *Ganoderma lucidum* and *A. rugosum*

Studies in Mycology

have been used biotechnologically in the production of biofuel and degradation of environmental pollutants (Jong *et al.* 2017, Wang *et al.* 2021).

The systematics of the *Ganodermataceae* have been carried out for about 100 years. Donk (1948) introduced *Ganodermataceae* as a family based on its unique double-walled basidiospores with obvious ornamentation on the endospore walls, which only included *Ganoderma* with a laccate pileal surface and truncated basidiospores and *Amauroderma* with globose to ellipsoid basidiospores without a truncated apex. Murrill (1905) introduced a genus *Tomophagus* that included pale-coloured basidiomata with pale and soft context and truncated basidiospores. In the past decades, specimens of *Ganodermataceae* have been collected from all over the world (Steyaert 1972, Moncalvo & Ryvarden 1997, Ryvarden 2004b, Hapuarachchi *et al.* 2019b) except for the polar region. More genera have been established by evidence of morphological characters and/or molecular data. Imazeki (1952) presented *Trachyderma* as a genus with a fleshy succulent context and truncated basidiospores with spinules. Steyaert (1972) examined several known species in *Ganoderma*, then established *Haddowia* based on non-truncated basidiospores with longitudinal ridges partly connected with short transverse walls on the endospore walls; *Humphreya* with reticular or erratic irregularly ridged double walls on truncated basidiospores; and *Magoderna* based on anticlinal hyphae in pileipellis and ellipsoid to ovoid basidiospores without truncated apex. Costa-Rezende *et al.* (2017) established *Foraminispora* according to the hollow columnar endospore ornamentation, which persist to the exospore wall sometimes forming holes on the basidiospores, and *Furtadoa* based on a monomitic hyphal system in context with clamped and simple-septate generative hyphae. Sun *et al.* (2020) studied one group of *Amauroderma* with a unique pore surface that changes to blood red when bruised, and established *Sanguinoderma*. Costa-Rezende *et al.* (2020b) established *Amaurodermellus* with a dull pileal surface and ovoid basidiospores, and *Cristataspora* with double-walled basidiospores which have endosporic ornamentation as vertical or transverse ridges.

However, the uncertainty about the family level of *Ganodermataceae* should not be ignored. Binder *et al.* (2013) carried out the phylogenetic and phylogenomic analyses of *Polyporales* based on 356 single-copy genes from 10 genomes of this order, which showed that *Ganoderma* was involved in the 'core polyporoid clade'. Justo *et al.* (2017) suggested *Ganodermataceae* as a synonym of *Polyporaceae* based on ITS, nLSU and *rpb1* sequences. The conclusions based on phylogenetic evidence have certain credibility, while in this study, *Ganodermataceae* is still regarded as an independent family based on its remarkable morphological features to clarify the intergeneric and interspecific relationships. For the time being, we prefer to treat *Ganodermataceae* as an independent family different from *Polyporaceae* according to previous specialised studies on the *Ganoderma* group (Moncalvo & Ryvarden 1997, Robledo *et al.* 2015, Zhou *et al.* 2015, Hapuarachchi *et al.* 2018a, b, 2019a, b, Xing *et al.* 2018, Costa-Rezende *et al.* 2020a, b, Sun *et al.* 2020, Luangharn et al. 2021). The scientific status of *Ganodermataceae* within the *Polyporales* should be considered in morphology, phylogeny, and even whole genome sequences.

Ongoing taxonomic studies of *Ganodermataceae* from Asia, Africa, Europe, Neotropics and North America have been conducted for a long time with many new species and combinations continually being reported (Otieno 1968, Steyaert 1972, Moncalvo & Ryvarden 1997, Ryvarden 2004a, b, Gibertoni *et al.* 2008, Cao *et al.* 2012, Le *et al.* 2012, Coetzee *et al.* 2015, Gomes-Silva *et al.* 2015, Hapuarachchi *et al.* 2019b, Sun *et al.* 2020, Costa-Rezende *et al.* 2020b). China has a complex and diverse natural environment resulting in high species richness, and a total of 130 species of *Ganodermataceae* have been reported (Zhao & Zhang 2000, Dai 2012, Cao & Yuan 2012, Wang & Wu 2014, Li *et al.* 2015, Zhou *et al.* 2015, Hapuarachchi *et al.* 2018b, Xing *et al.* 2018, Ye *et al.* 2019, Sun *et al.* 2020). The great variability in the macroscopic characters of the basidiomata and the relatively uniform macro- and micro-morphology of most species in *Ganodermataceae* have resulted in many confusions in taxonomy. As of 10 March 2022, there were 642 records of *Ganodermataceae* recorded in Index Fungorum (http://www.indexfungorum.org/), and 698 records in MycoBank (http://www.mycobank.org/). Nearly half of these records have been identified as synonyms, especially in *Ganoderma* and *Amauroderma* and it is necessary to assess the validity of these records.

With the rapid development of molecular techniques in recent years, DNA sequence data have been widely used in the taxonomic studies of *Ganodermataceae*. Moncalvo (1995) used ITS sequences and the D2 region of nLSU sequences to construct the relationships among species in *Ganoderma*, and concluded that the combined data is useful for intrageneric segregation while the D2 region is suitable for intergeneric or higher ranks segregation. Subsequently, ITS and nLSU sequences were often used to identify species (Cao *et al.* 2012, Le *et al.* 2012, de Lima Júnior *et al.* 2014, Gomes-Silva *et al.* 2015, Li *et al.* 2015). It is worth mentioning that Fryssouli *et al.* (2020) carried out a phylogenetic study of *Ganoderma* based only on 3 970 ITS sequences obtained from the GenBank/ENA/DDBJ database which evaluated the accuracy of sequences and showed that *Ganoderma* can be divided into five main lineages. However, for the complex groups in *Ganoderma* or for the higher rank classification of *Ganodermataceae*, most researchers use multi-gene datasets to construct phylogenetic trees (Zhou *et al.* 2015, Costa-Rezende *et al.* 2017, 2020b, Justo *et al.* 2017, Cabarroi-Hernández *et al.* 2019, Hapuarachchi *et al.* 2019b, Luangharn *et al.* 2020, Sun *et al.* 2020). At present, eight genes have been applied to the phylogenetic analyses in *Ganodermataceae*, *viz*., the internal transcribed spacer regions (ITS), the large subunit of nuclear ribosomal RNA gene (nLSU), the largest subunit of RNA polymerase II gene (*rpb1*), the second largest subunit of RNA polymerase II gene (*rpb2*), the translation elongation factor 1-α gene (*tef1*), the β-tubulin gene (*tub*), the small subunit mitochondrial rRNA gene (mtSSU) and the small subunit nuclear ribosomal RNA gene (nSSU). According to the records in GenBank (https://www.ncbi.nlm.nih.gov/) as of 21 April 2021, 150 801 items were found by searching '*Ganodermataceae*' directly, but only about 65 000 items among them were identified as species of *Ganodermataceae*. The number of sequences is considerable, but repetitive sequences of the same species or specimens, inaccurate identification and low quality of sequences make it necessary to select only the reliable molecular data for phylogenetic analyses.

In this study, the specimens collected from all over the world were studied by macromorphological and microscopic examinations together with ultrastructural observations and phylogenetic analyses based on six gene loci (ITS, nLSU, *rpb2*, *tef1*, mtSSU and nSSU). A total of 146 species in *Ganodermataceae* with available DNA sequences were involved in the phylogenetic analyses. Based on morphological characters and phylogenetic evidence, 14 genera were confirmed within *Ganodermataceae*, *Furtadoella gen. nov.*, *Neoganoderma gen. nov.*, *Sinoganoderma gen. nov.* and *Trachydermella gen. nov.* were proposed as new genera;

278 species were confirmed in *Ganodermataceae* including 23 new species which are listed in Table 2. The ultrastructural features observed under SEM of basidiospores of 10 genera in *Ganodermataceae* were described and photographed. In total, 56 species and nine genera are described and illustrated here. A key to accepted genera of *Ganodermataceae* and keys to accepted species of *Ganoderma*, *Haddowia*, *Humphreya*, *Magoderna*, *Sanguinoderma*, *Tomophagus* are also provided.

MATERIALS AND METHODS

Morphological studies

The studied specimens are deposited at the fungaria of the Institute of Microbiology, Beijing Forestry University (BJFC, Beijing, China), the Institute of Applied Ecology, Chinese Academy of Sciences (IFP, Shenyang, China), the private fungarium of J. Vlasák of Czech Republic (JV) and the Universidade Federal de Pernambuco, Brazil (URM). Macro-morphological descriptions of the new taxa (or selected taxa) were based on field notes and fungarium specimens. Special colour terms followed Petersen (1996). Micro-morphological data were obtained from dried specimens and observed under a compound microscope following Cui *et al.* (2019) and Sun *et al.* (2020). Sections were studied at a magnification up to 1 000× using Nikon E80i microscope and phase contrast illumination (Nikon, Tokyo, Japan). Line drawings were made with the aid of a drawing tube. Ultrastructure of basidiospores was observed with Scanning Electron Microscopy (SEM) using a Field Emission Scanning Electron Microscope (FESEM) Hitachi SU-8010 (Hitachi, Ltd, Tokyo, Japan) at Beijing Forestry University, China (BJFU). Microscopic features, measurements and drawings were made from slide preparations stained with Cotton Blue and Melzer's reagent. Spores were measured from sections cut from the tubes. To represent the variation in the size of the basidiospores, 5 % of measurements were excluded from each end of the range, and are given in parentheses. The following abbreviations are used: IKI = Melzer's reagent, IKI – = neither amyloid nor dextrinoid, KOH = 5 % potassium hydroxide, CB = Cotton Blue, CB + = cyanophilous, L = mean spore length (arithmetic average of all spores), W = mean spore width (arithmetic average of all spores), Q = variation in the L/W ratios between the specimens studied, n (a/b) = number of spores: (a) measured from given number, (b) of specimens.

DNA extraction, amplification and sequencing

A cetyl trimethylammonium bromide (CTAB) rapid plant genome extraction kit-DN14 (Aidlab Biotechnologies Co., Ltd, Beijing, China) and a FH plant DNA kit II (Demeter Biotech Co., Ltd., Beijing, China) were used to extract total genomic DNA from dried specimens and to perform the polymerase chain reaction (PCR) according to the manufacturer's instructions with some modifications (Xing *et al.* 2018, Sun *et al.* 2020). The ITS regions were amplified with primer pairs ITS5 and ITS4 (White *et al.* 1990). The nLSU regions were amplified with primer pairs LR0R and LR7, and the primer LR5 was used sometimes as an alternative to LR7 (Vilgalys & Hester 1990). The *rpb2* regions were amplified with primer pairs fRPB2-5F and fRPB2-7CR (Liu *et al.* 1999). The *tef1* regions were amplified with primer pairs EF1-983F and EF1-1567R (Rehner & Buckley 2005). The mtSSU regions were amplified with primer pairs MS1 and MS2 (White *et al.* 1990). The nSSU regions were amplified with primer pairs PNS1 and NS41 (White *et al.* 1990).

The PCR cycling schedule for ITS, *tef1* and mtSSU included an initial denaturation at 95 °C for 3 min, followed by 35 cycles at 94 °C for 40 s, 54 °C for ITS and mtSSU, 55 °C for *tef1* for 45 s, 72 °C for 1 min, and a final extension at 72 °C for 10 min. The PCR cycling schedule for nLSU and nSSU included an initial denaturation at 94 °C for 1 min, followed by 35 cycles at 94 °C for 30 s, 50 °C for nLSU and 53 °C for nSSU for 1 min, 72 °C for 1.5 min, and a final extension at 72 °C for 10 min. The PCR cycling schedule for *rpb2* included an initial denaturation at 94 °C for 2 min, followed by 10 cycles at 94 °C for 40 s, 60 °C for 40 s and 72 °C for 2 min, then followed by 37 cycles at 94 °C for 45 s, 55 °C for 1.5 min and 72 °C for 2 min, and a final extension of 72 °C for 10 min. The PCR products were purified and sequenced at the Beijing Genomics Institute (BGI), China, with the same primers. All sequences analysed in this study were deposited at GenBank and are listed in Table 1.

Phylogenetic analyses

The sequences generated in this study and retrieved from GenBank were combined with ITS, nLSU, *rpb2*, *tef1*, mtSSU and nSSU. *Perenniporia subtephropora* was selected as the outgroup (Xing 2019). Phylogenetic analyses used in this study followed the approach of Song & Cui (2017) and Shen *et al.* (2019). All sequences of ITS, nLSU, *rpb2*, *tef1*, mtSSU and nSSU were respectively aligned in MAFFT v. 7 (Katoh & Standley 2013, https://mafft.cbrc.jp/alignment/server/) and manually adjusted in BioEdit v. 7.0.9. (Hall 1999). Alignments were spliced in Mesquite v. 3.2. (Maddison & Maddison 2017). The partition homogeneity test (PHT) (Farris *et al.* 1994) of the six-gene dataset was tested by PAUP v. 4.0b10 (Swofford 2002) under 1 000 homogeneity replicates. The best-fit evolutionary model was selected by hierarchical likelihood ratio tests (hLRT) and Akaike information criterion (AIC) in MrModeltest v. 2.3 (Nylander 2004) after scoring 24 models of evolution by PAUP v. 4.0b10.

The Maximum Likelihood (ML) and Bayesian Inference (BI) analyses were performed based on the combined dataset. Each gene of ITS, nLSU, *rpb2*, *tef1*, mtSSU and nSSU was used to perform ML analyses respectively. The ML analyses were performed in RAxML-HPC v. 8.2.3 (Stamatakis 2014) and involved 1 000 ML searches under the GTRGAMMA model, and only the Maximum Likelihood best tree from all searches was provided. In addition, 1 000 rapid bootstrap replicates were run with the GTRCAT model to assess ML bootstrap values of the nodes. Bayesian Inference was calculated using MrBayes v. 3.1.2 (Ronquist & Huelsenbeck 2003) with four Markov chains, starting trees for 80 M generations until the split deviation frequency < 0.01, and trees were sampled every 100 generations. The first 25 % of the sampled trees were discarded as burn-in and the remaining ones were used to reconstruct a majority rule consensus and calculate Bayesian Posterior Probabilities (BPP) of the clades.

All trees were viewed in FigTree v. 1.4.2 (http://tree.bio.ed.ac.uk/software/figtree/). The ML bootstrap support values ≥ 50 % and Bayesian Posterior Probabilities ≥ 0.95 were presented on topologies from ML analyses respectively. The final alignments and the retrieved topologies were deposited in TreeBASE (http:// www.treebase.org), under accession ID: 27788 (http://purl.org/phylo/treebase/phylows/study/TB2:S27788).

Table 1. Taxa information and GenBank accession numbers of the sequences used in this study. Species in bold are new species or new combinations.

		GenBank accession No.						
Species	**Voucher**	**ITS**	**nLSU**	***rpb2***	***tef1***	**mtSSU**	**nSSU**	**References**
Amauroderma aurantiacum	FLOR 52205	KR816510	KU315205	–	–	–	–	Costa-Rezende *et al.* (2016)
	DHCR540	MF409961	MF409953	–	–	–	–	Costa-Rezende *et al.* (2017)
A. calcigenum	FLOR 52315	KR816514	–	–	–	–	–	Costa-Rezende *et al.* (2016)
	URM 89213	MK119792	MK119870	MK121484	MK121541	MZ352778[a]	MZ355137[a]	Sun *et al.* (2020), this study
	JV 1808/51	MZ354865[a]	MZ354997[a]	MZ245374[a]	MZ221624[a]	MZ352779[a]	MZ355138[a]	This study
	URM83864	JX982565	–	–	–	–	–	Gomes-Silva *et al.* (2015)
	URM86847	KT006601	–	–	–	–	–	Gomes-Silva *et al.* (2015)
	URM 89566	MZ354866[a]	MZ355111[a]	MZ245375[a]	MZ221625[a]	MZ352780[a]	MZ355146[a]	This study
A. calcitum	FLOR 50931/DHCR538	KR816528	KU315207	–	–	–	–	Costa-Rezende *et al.* (2016)
	FLOR 52230 (TYPE)	KR816529	–	–	–	–	–	Costa-Rezende *et al.* (2016)
A. camerarium	FLOR 52169	KR816523	–	–	–	–	–	Costa-Rezende *et al.* (2016)
	FLOR 52216	KR816509	–	–	–	–	–	Costa-Rezende *et al.* (2016)
A. cf. schomburgkii	URM 89271	MK119802	MK119880	MK121495	MK121552	–	MZ355289[a]	Sun *et al.* (2020), this study
	URM 89272	MK119803	MK119881	MK121496	MK121553	–	MZ355280[a]	Sun *et al.* (2020), this study
	JV 1908/39	MZ354989[a]	MZ354999[a]	MZ245376[a]	MZ221626[a]	–	MZ355147[a]	This study
A. elegantissimum	Dai 17431	MK119794	MK119872	MK121493	MK121543	–	MZ355288[a]	Sun *et al.* (2020), this study
	URM 83822	MK119795	MK119873	MK121494	MK121544	MZ352784[a]	MZ355308[a]	Sun *et al.* (2020), this study
A. exile	URM82794	JX310845	–	–	–	–	–	Gomes-Silva *et al.* (2015)
	URM 89226	MK119796	MK119874	–	MK121545	–	MZ355249[a]	Sun *et al.* (2020), this study
A. floriformum	URM83250 (TYPE)	JX310846	–	–	–	–	–	Gomes-Silva *et al.* (2015)
A. intermedium	GAS910	MF409959	–	–	–	–	–	Costa-Rezende *et al.* (2017)
	FLOR 52248	KR816527	KU315209	–	–	–	–	Costa-Rezende *et al.* (2016)
	JV 1312/E14-J	MZ354868[a]	MZ355096[a]	–	MZ221627[a]	–	MZ355151[a]	This study
A. laccatostipitatum	HFSL ACGS7	KT006602	–	–	–	–	–	Gomes-Silva *et al.* (2015)
	URM 89240	MK119797	MK119875	MK121489	MK121546	MZ352781[a]	MZ355262[a]	Sun *et al.* (2020), this study
A. omphalodes	DHCR499/501	MF409956	MF409951	–	MF421238	–	–	Costa-Rezende *et al.* (2017)
	DHCR500	MF409957	MF409952	–	MF421239	–	–	Costa-Rezende *et al.* (2017)
	JV 1909/23-J	MZ354991[a]	MZ355000[a]	MZ245377[a]	MZ221628[a]	MZ352785[a]	MZ355250[a]	This study
A. partitum	URM82882	JX310852	–	–	–	–	–	Gomes-Silva *et al.* (2015)
	URM83039	JX310853	–	–	–	–	–	Gomes-Silva *et al.* (2015)
A. praetervisum	URM 89233	MK119801	MK119879	MK121486	MK121551	MZ352926[a]	MZ355315[a]	Sun *et al.* (2020), this study

Table 1. (Continued).

Species	Voucher	GenBank accession No.						References
		ITS	nLSU	*rpb2*	*tef1*	mtSSU	nSSU	
	JV 1467/40	MZ354867[a]	–	–	–	–	–	This study
A. pseudoboletum	FLOR 52318	KR816516	–	–	–	–	–	Costa-Rezende *et al.* (2016)
A. robledoi	FLOR 52249	KR816511	–	–	–	–	–	Costa-Rezende *et al.* (2016)
	URM84230	KC348461	–	–	–	–	–	Unpublished
	URM 87687	MK119800	MK119878	MK121487	MK121550	MZ352786[a]	MZ355290[a]	Sun *et al.* (2020), this study
A. schomburgkii	JV 1908/9	MZ354990[a]	–	–	MZ221629[a]	–	MZ355152[a]	This study
	URM 89225	MK119805	MK119883	MK121498	MK121555	–	MZ355324[a]	Sun *et al.* (2020), this study
	URM83228	JX310848	KT006621	–	–	–	–	Gomes-Silva *et al.* (2015)
Amauroderma sp.	URM 89239	MZ354869[a]	MZ355112[a]	MZ245378[a]	MZ221630[a]	MZ352927[a]	MZ355253[a]	This study
A. subsessile	URM 89293	MK119806	MK119885	MK121490	MK121556	MZ352782[a]	MZ355319[a]	Sun *et al.* (2020), this study
	URM 89294	MK119807	MK119886	MK121491	MK121557	MZ352783[a]	MZ355317[a]	Sun *et al.* (2020), this study
Amaurodermellus ovisporum	DHCR127 (FLOR)	MN077530	–	–	–	–	–	Costa-Rezende *et al.* (2020b)
	DHCR546 (HUEFS)	MN077528	–	–	–	–	–	Costa-Rezende *et al.* (2020b)
	DHCR547 (HUEFS)	MN077527	MN077553	–	–	–	–	Costa-Rezende *et al.* (2020b)
	DHCR539 (HUEFS)	MN077529	–	–	–	–	–	Costa-Rezende *et al.* (2020b)
Cristataspora coffeata	FLOR 50933	KU315204	–	–	–	–	–	Costa-Rezende *et al.* (2020b)
	1504/50	MZ354891[a]	–	–	MZ221631[a]	–	–	This study
	Robledo 3183 (FCOS)	MN077526	MN077560	–	MN061695	–	–	Costa-Rezende *et al.* (2020b)
	Robledo 3182 (FCOS)	MN077525	MN077559	–	–	–	–	Costa-Rezende *et al.* (2020b)
C. flavipora	G299	MN077521	MN077555	–	MN061694	–	–	Costa-Rezende *et al.* (2020b)
Foraminispora austrosinensis	Cui 16425	MK119809	MK119888	–	MK121559	MZ352835[a]	MZ355257[a]	Sun *et al.* (2020), this study
	Cui 14318	MK119810	MK119889	–	MK121560	MZ352848[a]	MZ355309[a]	Sun *et al.* (2020), this study
Fo. concentrica	Cui 12644 (TYPE)	MK119812	MK119891	MK121499	MK121561	MZ352839[a]	MZ355310[a]	Sun *et al.* (2020), this study
	Cui 16238	MK119816	MK119895	–	MK121565	MZ352840[a]	MZ355279[a]	Sun *et al.* (2020), this study
	Cui 17141	MZ354892[a]	MZ355001[a]	MZ245379[a]	–	MZ352837[a]	MZ355311[a]	This study
	Cui 12648	MK119815	MK119894	MK121501	MK121564	MZ352849[a]	MZ355314[a]	Sun *et al.* (2020), this study
Fo. rugosa	DHCR512	MF409960	–	–	MF421240	–	–	Costa-Rezende *et al.* (2017)
	DHCR560	MF409963	MF409955	–	MF421241	–	–	Costa-Rezende *et al.* (2017)
	URM 86888	MZ354945[a]	MZ355131[a]	MZ245380[a]	–	MZ352921[a]	MZ355277[a]	This study
	JV 1608/889-ND	MZ354946[a]	–	–	–	MZ352919[a]	–	This study
Fo. yinggelingensis	Cui 13618 (TYPE)	MK119821	MK119900	MK121536	MK121570	MZ352838[a]	MZ355275[a]	Sun *et al.* (2020), this study

Table 1. (Continued).

Species	Voucher	GenBank accession No.						References
		ITS	nLSU	*rpb2*	*tef1*	mtSSU	nSSU	
	Cui 13630	MK119822	MK119901	–	–	MZ352836[a]	MZ355276[a]	Sun *et al.* (2020), this study
Fo. yunnanensis	Cui 7974	KJ531653	KU220013	–	–	MZ352841[a]	–	Li & Yuan (2015), this study
	Yuan 2253	KJ531655	–	–	–	–	–	Li & Yuan (2015)
Furtadoella biseptata	FLOR 50932 (TYPE)	KU315196	KU315206	–	–	–	–	Costa-Rezende *et al.* (2016)
Fu. brasiliensis	URM83578	JX310841	–	–	–	–	–	Gomes-Silva *et al.* (2015)
	TBG58	JX982569	–	–	–	–	–	Gomes-Silva *et al.* (2015)
	JV 1909/75	MZ354994[a]	MZ355100[a]	MZ245381[a]	MZ221632[a]	MZ352922[a]	MZ355214[a]	This study
Ganoderma acaciicola	Cui 16813	MZ354893[a]	MZ355003[a]	MZ245382[a]	–	–	MZ355221[a]	This study
	Cui 16814	MZ354894[a]	MZ355004[a]	MZ245383[a]	–	–	MZ355219[a]	This study
	Cui 16815 (TYPE)	MZ354895[a]	MZ355005[a]	MZ245384[a]	–	–	MZ355282[a]	This study
G. acontextum	JV 0611/21G (TYPE)	KF605667	–	MG367489	MG367538	–	–	This study
	JV 1208/11J	KF605668	–	MG367490	MG367540	–	–	This study
	JV 1407/64	MG279151	–	MG367491	MG367539	–	–	This study
G. adspersum	Dai 13191	MG279153	–	MG367492	MG367541	–	MZ355157[a]	Xing *et al.* (2018), this study
	HSBU-200894	MG279154	–	–	MG367542	–	MZ355158[a]	Xing *et al.* (2018), this study
G. alpinum	Cui 18402	MZ354910[a]	–	–	–	–	–	This study
	Cui 17325	MZ354911[a]	–	–	–	–	–	This study
	Cui 17467 (TYPE)	MZ354912[a]	–	–	–	–	–	This study
G. angustisporum	Cui 13817 (TYPE)	MG279170	MZ355090[a]	MG367507	MG367563	MZ352850[a]	MZ355166[a]	Xing *et al.* (2018), this study
	Dai 19603	MZ354978[a]	MZ355047[a]	MZ245385[a]	MZ221633[a]	MZ352856[a]	MZ355207[a]	This study
	Cui 18240	MZ354979[a]	MZ355074[a]	MZ245386[a]	MZ221634[a]	MZ352851[a]	MZ355246[a]	This study
G. applanatum	Cui 14062	MZ354913[a]	MZ355076[a]	MZ358846[a]	MZ221635[a]	MZ352857[a]	MZ355202[a]	This study
	Cui 14070	MZ354914[a]	MZ355079[a]	MZ245387[a]	MZ221636[a]	–	MZ355203[a]	This study
G. aridicola	Dai 12588 (TYPE)	KU572491	–	–	KU572502	MZ352842[a]	MZ355195[a]	Xing *et al.* (2016), this study
	GanoTK01	JN105707	–	–	–	JN105734	–	Unpublished
	GanoTK25	JN105708	–	–	–	JN105719	–	Unpublished
G. australe	DHCR411	MF436675	MF436672	–	MF436677	–	–	Costa-Rezende *et al.* (2017)
	DHCR417	MF436676	MF436673	–	MF436678	–	–	Costa-Rezende *et al.* (2017)
G. austroafricanum	CBS 138724	KM507324	KM507325	MK611970	–	–	–	Coetzee *et al.* (2015)
G. boninense	WD 2085	KJ143906	–	KJ143965	KJ143925	–	–	Zhou *et al.* (2015)
	WD 2028	KJ143905	KU220015	KJ143964	KJ143924	–	–	Zhou *et al.* (2015)

Table 1. (Continued).

Species	Voucher	GenBank accession No.						References
		ITS	nLSU	*rpb2*	*tef1*	mtSSU	nSSU	
G. brownii	JV 1105/9J	MG279159	–	MG367494	MG367547	–	–	Xing *et al.* (2018)
	JV 0709/109	KF605662	–	MG367495	MG367548	–	–	Unpublished
G. bubalinomarginatum	Dai 20074	MZ354926[a]	MZ355010[a]	MZ245388[a]	MZ221637[a]	MZ352881[a]	MZ355312[a]	This study
	Dai 20075 (TYPE)	MZ354927[a]	MZ355040[a]	MZ245389[a]	MZ221638[a]	MZ352882[a]	MZ355224[a]	This study
G. calidophilum	MFLU 19-2174	MN398337	–	–	–	–	–	Luangharn *et al.* (2021)
	MFLU 19-2219	MN398338	–	–	–	–	–	Luangharn *et al.* (2021)
G. carnosum	MUCL 49464	MG706220	MG706168	–	–	–	–	Unpublished
	LGAM 1642	MG706217	MG706165	–	–	–	–	Unpublished
G. carocalcareum	DMC 322 (TYPE)	EU089969	–	–	–	–	–	Douanla-Meli & Langer (2009)
	DMC 513	EU089970	–	–	–	EU089971	–	Douanla-Meli & Langer (2009)
G. castaneum	Dai 16500	MZ354918[a]	–	MZ245390[a]	MZ221639[a]	MZ352914[a]	MZ355173[a]	This study
	Cui 13893	MZ354919[a]	MZ355013[a]	MZ245391[a]	MZ221640[a]	MZ352915[a]	MZ355185[a]	This study
	Dai 13710	KU572489	MZ355045[a]	–	KU572499	MZ352917[a]	MZ355229[a]	Xing *et al.* (2016), this study
	Cui 17283 (TYPE)	MZ354920[a]	–	–	–	MZ352916[a]	MZ355230[a]	This study
G. casuarinicola	Dai 16336 (TYPE)	MG279173	MZ355103[a]	MG367508	MG367565	MZ352843[a]	MZ355297[a]	Xing *et al.* (2018), this study
	Dai 16337	MG279174	MZ355104[a]	MG367509	MG367566	MZ352844[a]	MZ355196[a]	Xing *et al.* (2018), this study
	Dai 19678	MZ354995[a]	MZ355105[a]	–	MZ221641[a]	MZ352845[a]	MZ355204[a]	This study
	Dai 19470	MZ354996[a]	–	MZ245392[a]	MZ221642[a]	–	MZ355142[a]	This study
G. chalceum	URM80457	JX310812	JX310826	–	–	–	–	De Lima Júnior *et al.* (2014)
G. chocoense	QCAM 3123 (TYPE)	MH890527	–	–	–	–	–	Crous *et al.* (2018)
G. chuxiongense	Cui 17262 (TYPE)	MZ354907[a]	–	–	–	MZ352925[a]	MZ355316[a]	This study
G. cocoicola	Cui 16791 (TYPE)	MZ354984[a]	MZ355091[a]	MZ245393[a]	MZ221643[a]	–	MZ355321[a]	This study
	Cui 16792	MZ354985[a]	MZ355092[a]	MZ245394[a]	MZ221644[a]	–	MZ355278[a]	This study
G. concinnum	Robledo 3192	MN077522	MN077556	–	–	–	–	Costa-Rezende *et al.* (2020b)
	Robledo 3235	MN077523	MN077557	–	–	–	–	Costa-Rezende *et al.* (2020b)
G. cupreum	GanoTK4	JN105701	–	–	–	JN105732	–	Unpublished
	GanoTK7	JN105702	–	–	–	JN105730	–	Unpublished
G. curtisii	CBS 100131	JQ781848	–	KJ143966	KJ143926	–	–	Cao *et al.* (2012), Zhou *et al.* (2015)
	CBS 100132	JQ781849	–	KJ143967	KJ143927	–	–	Cao *et al.* (2012), Zhou *et al.* (2015)
G. destructans	CMW43670 (TYPE)	KR183856	–	–	–	–	–	Coetzee *et al.* (2015)
	Dai 16431	MG279177	–	–	–	–	–	Xing *et al.* (2018)

Table 1. (Continued).

Species	Voucher	GenBank accession No.						References
		ITS	nLSU	*rpb2*	*tef1*	mtSSU	nSSU	
G. dunense	CMW42149	MG020248	–	–	MG020226	–	–	Tchotet Tchoumi *et al.* (2018)
	CMW42157 (TYPE)	MG020255	–	–	MG020227	–	–	Tchotet Tchoumi *et al.* (2018)
G. ecuadorense	Dai 17397	MZ354950[a]	MZ355019[a]	MZ245398[a]	MZ221648[a]	–	MZ355180[a]	This study
	Dai 17418	MZ354951[a]	MZ355020[a]	MZ245399[a]	MZ221649[a]	–	MZ355181[a]	This study
	JV 1808/85	MZ354952[a]	MZ355075[a]	–	MZ221650[a]	–	MZ355247[a]	This study
G. eickeri	CMW50325	MH571689	–	–	MH567290	–	–	Tchotet Tchoumi *et al.* (2019)
	CMW49692 (TYPE)	MH571690	–	–	MH567287	–	–	Tchotet Tchoumi *et al.* (2019)
	Dai 12595	MZ354964[a]	MZ355035[a]	–	MZ221651[a]	–	MZ355159[a]	This study
	Dai 12598	MZ354965[a]	MZ355036[a]	–	MZ221652[a]	–	MZ355160[a]	This study
G. ellipsoideum	MFLU 19-2221	MN398339	–	–	–	–	–	Luangharn *et al.* (2021)
	CMW 14080966 (TYPE)	MH106867	–	–	–	–	–	Hapuarachchi *et al.* (2018b)
	Dai 19683	MZ354970[a]	MZ355018[a]	–	MZ221653[a]	MZ352893[a]	MZ355217[a]	This study
	Dai 20544	MZ354971[a]	MZ355033[a]	MZ245400[a]	MZ221654[a]	MZ352895[a]	MZ355205[a]	This study
G. enigmaticum	CMW43669 (TYPE)	KR183855	KR183859	–	–	–	–	Coetzee *et al.* (2015)
	Dai 15970	KU572486	MZ355106[a]	MG367513	KU572496	MZ352846[a]	MZ355197[a]	Xing *et al.* (2016, 2018), this study
	Dai 15971	KU572487	MZ355107[a]	MG367514	KU572497	MZ352847[a]	MZ355198[a]	Xing *et al.* (2016, 2018), this study
G. fallax	JV 1009/27 (TYPE)	KF605655	–	–	–	–	–	This study
	JV 0709/39	KF605658	–	–	–	–	–	This study
	JV 0509/93K	KF605653	–	–	–	–	–	This study
G. flexipes	Cui 13841	MZ354923[a]	MZ355063[a]	MZ245401[a]	MZ221655[a]	MZ352905[a]	MZ355177[a]	This study
	Cui 13863	MZ354924[a]	MZ355064[a]	MZ245402[a]	MZ221656[a]	–	MZ355178[a]	This study
	Dai 20461	MZ354925[a]	MZ355065[a]	MZ245403[a]	MZ221657[a]	–	MZ355153[a]	This study
G. fomicatum	BCRC35374	JX840349	–	–	–	–	–	Wang *et al.* (2014)
	TNM-F0010592	JX840347	–	–	–	–	–	Wang *et al.* (2014)
G. gibbosum	KUMCC17-0003	MH035681	MH553157	–	–	–	–	Luangharn *et al.* (2020)
	KUMCC17-0005	MH035682	MH553158	–	–	–	–	Luangharn *et al.* (2020)
	Cui 13940	MZ354972[a]	MZ355021[a]	MZ245404[a]	MZ221658[a]	MZ352894[a]	MZ355161[a]	This study
	Cui 14338	MZ354969[a]	MZ355014[a]	MZ245405[a]	MZ221659[a]	MZ352876[a]	MZ355162[a]	This study
	Cui 17769	MZ354967[a]	–	–	–	–	–	This study
	Cui 17780	MZ354968[a]	–	–	–	–	–	This study
	Cui 17254	MZ354966[a]	MZ355115[a]	MZ245406[a]	MZ221660[a]	MZ352877[a]	MZ355286[a]	This study

Table 1. (Continued).

Species	Voucher	GenBank accession No.						References
		ITS	nLSU	*rpb2*	*tef1*	mtSSU	nSSU	
G. guangxiense	Cui 14453 (TYPE)	MZ354939[a]	MZ355037[a]	MZ245407[a]	MZ221661[a]	MZ352896[a]	MZ355163[a]	This study
	Cui 14454	MZ354941[a]	MZ355039[a]	MZ245408[a]	MZ221662[a]	MZ352897[a]	MZ355164[a]	This study
	Cui 14508	MZ354940[a]	MZ355038[a]	–	MZ221663[a]	MZ352865[a]	MZ355240[a]	This study
G. hochiminhense	MFLU 19-2224 (TYPE)	MN398324	MN396390	–	MN423176	–	–	Luangharn *et al.* (2021)
	MFLU 19-2225	MN396662	MN396391	–	MN423177	–	–	Luangharn *et al.* (2021)
	Cui 18229	MZ354986[a]	MZ355094[a]	MZ245409[a]	MZ221664[a]	–	MZ355283[a]	This study
	Dai 18488	MZ354987[a]	MZ355093[a]	MZ245410[a]	MZ221665[a]	–	MZ355218[a]	This study
G. hoehnelianum	Cui 13904	MZ354935[a]	MZ355135[a]	MZ245411[a]	MZ221666[a]	MZ352888[a]	MZ355169[a]	This study
	Cui 13982	MG279178	MZ355071[a]	MG367515	MG367570	–	MZ355170[a]	Xing *et al.* (2018), this study
	Dai 20783	–	MZ355002[a]	MZ245412[a]	MZ221667[a]	MZ352892[a]	MZ355255[a]	This study
G. japonicum	AS569	AY593864	–	–	–	–	–	Wang & Yao (2005)
	Gja-1	GU213475	–	–	–	–	–	Unpublished
G. knysnamense	CMW47755 (TYPE)	MH571681	–	–	MH56726	–	–	Tchotet Tchoumi *et al.* (2019)
	CMW49688	MH571683	–	–	MH567266	–	–	Tchotet Tchoumi *et al.* (2019)
G. leucocontextum	Dai 15601	KU572485	MZ355049[a]	MG367516	KU572495	MZ352899[a]	MZ355318[a]	Xing *et al.* (2018), this study
	GDGM 40200 (TYPE)	KF011548	–	–	–	–	–	Li *et al.* (2015)
G. lingzhi	Wu 1006-38 (TYPE)	JQ781858	–	JX029980	JX029976	–	–	Cao *et al.* (2012)
	Cui 9166	KJ143907	–	JX029978	JX029974	JX029987	–	Zhou *et al.* (2015)
	Dai 20895	MZ354904[a]	MZ355006[a]	MZ245413[a]	MZ221668[a]	–	–	This study
	Cui 18161	MZ354905[a]	–	–	–	–	–	This study
	Cui 18167	MZ354906[a]	–	–	–	–	–	This study
G. lobatum	JV 1008/31	KF605671	–	MG367499	MG367553	–	–	Xing *et al.* (2018)
	JV 1008/32	KF605670	–	MG367500	MG367554	–	–	Xing *et al.* (2018)
G. lucidum	Cui 14404	MG279181	MZ355051[a]	MG367519	MG367573	MZ352858[a]	MZ355191[a]	Xing *et al.* (2018), this study
	Cui 14405	MG279182	MZ355089[a]	MG367520	MG367574	–	MZ355194[a]	Xing *et al.* (2018), this study
	K 175217	KJ143911	–	KJ143971	KJ143929	–	–	Zhou *et al.* (2015)
	MT 26/10	KJ143912	–	–	KJ143930	–	–	Zhou *et al.* (2015)
	Dai 20017	MZ354937[a]	MZ355050[a]	–	MZ221669[a]	–	MZ355256[a]	This study
G. magniporum	Zhou 439	MZ354936[a]	MZ355097[a]	–	–	MZ352863[a]	–	This study
	Dai 19966	–	MZ355098[a]	MZ345728[a]	MZ221670[a]	–	MZ355223[a]	This study
G. martinicense	LIP SW-Mart08-55 (TYPE)	KF963256	–	–	–	–	–	Unpublished

Table 1. (Continued).

Species	Voucher	GenBank accession No.						References
		ITS	nLSU	*rpb2*	*tef1*	mtSSU	nSSU	
	He 2240	MG279163	–	MG367503	MG367557	–	–	Xing *et al.* (2018)
G. mastoporum	K15-86	MF680427	–	–	–	–	–	Unpublished
	TNM-F0018835	JX840351	–	–	–	–	–	Wang *et al.* (2014)
G. mbrekobenum	UMN7-3 GHA (TYPE)	KX000896	KX000897	–	–	–	–	Crous *et al.* (2016)
	UMN7-4 GHA	KX000898	KX000899	–	–	–	–	Crous *et al.* (2016)
G. meredithiae	UMNFL50	MG654103	–	–	–	–	–	Loyd *et al.* (2018)
	UMNFL64	MG654106	–	MG754863	–	–	–	Loyd *et al.* (2018)
G. mexicanum	MUCL 49453	MK531811	–	MK531836	MK531825	–	–	Cabarroi-Hernández *et al.* (2019)
	MUCL 55832	MK531815	–	MK531839	MK531829	–	–	Cabarroi-Hernández *et al.* (2019)
G. mirabile	Cui 16408	–	MZ355066[a]	–	MZ221671[a]	–	MZ355227[a]	This study
	Cui 18271	MZ354958[a]	MZ355067[a]	MZ345729[a]	MZ221672[a]	MZ352860[a]	MZ355231[a]	This study
	Cui 18283	MZ354959[a]	MZ355069[a]	MZ345730[a]	MZ221673[a]	MZ352861[a]	MZ355248[a]	This study
	Cui 18237	MZ354960[a]	MZ355068[a]	MZ345731[a]	MZ221674[a]	MZ352862[a]	MZ355243[a]	This study
G. mizoramense	UMN-MZ4 (TYPE)	KY643750	–	–	–	–	–	Crous *et al.* (2017a)
	UMN-MZ5	KY643751	KY747490	–	–	–	–	Crous *et al.* (2017a)
	JZ8	MG437336	–	–	–	–	–	Unpublished
G. multipileum	Cui 13597	MZ354899[a]	MZ355043[a]	MZ345732[a]	MZ221675[a]	MZ352866[a]	MZ355174[a]	This study
	Dai 17569	MZ354896[a]	MZ355007[a]	MZ345733[a]	MZ221676[a]	MZ352867[a]	MZ355175[a]	This study
	Dai 19690	MZ354897[a]	MZ355008[a]	–	MZ221677[a]	MZ352868[a]	MZ355215[a]	This study
	Dai 19691	MZ354898[a]	MZ355041[a]	–	–	MZ352869[a]	–	This study
G. multiplicatum	SPC9	KU569553	KU570951	–	–	–	–	Bolaños *et al.* (2016)
	CC8	KU569515	KU570915	–	–	–	–	Bolaños *et al.* (2016)
	URM83346	JX310823	JX310837	–	–	–	–	De Lima Júnior *et al.* (2014)
	Dai 17395	MZ354903[a]	–	MZ345734[a]	MZ221678[a]	MZ352870[a]	MZ355209[a]	This study
G. mutabile	Yuan 2289 (TYPE)	JN383977	–	–	–	–	–	Cao & Yuan (2012)
	Cui 17189	MZ354976[a]	–	–	MZ221679[a]	–	–	This study
	Dai 20414	MZ354977[a]	MZ355110[a]	MZ345735[a]	MZ221680[a]	MZ352864[a]	MZ355292[a]	This study
G. myanmarense	MFLU 19-2167 (TYPE)	MN396330	MN428672	–	–	–	–	Luangharn *et al.* (2021)
	MFLU 19-2211/2169	MN396329	MN398325	–	–	–	–	Luangharn *et al.* (2021)
G. nasalanense	CACP17060211 (TYPE)	MK345441	MK346831	–	–	–	MK346842	Hapuarachchi *et al.* (2019b)
	CACP17060212	MK345442	MK346832	–	–	–	MK346843	Hapuarachchi *et al.* (2019b)

Table 1. (Continued).

Species	Voucher	GenBank accession No.						References
		ITS	nLSU	*rpb2*	*tef1*	mtSSU	nSSU	
G. neojaponicum	AS5.541 (TYPE)	AY593866	–	–	–	–	–	Wang & Yao (2005)
	36073	AY335163	–	–	–	–	–	Unpublished
G. nitidum	JV 1504/73	MZ354933[a]	–	–	MZ221681[a]	MZ352883[a]	–	This study
G. orbiforme	Cui 13880	MG279187	MZ355016[a]	MG367523	MG367577	MZ352908[a]	MZ355188[a]	Xing *et al.* (2018), this study
	Cui 13891	MZ354953[a]	MZ355017[a]	MZ345736[a]	MZ221682[a]	MZ352910[a]	MZ355167[a]	This study
	Cui 18301	MZ354954[a]	MZ355070[a]	–	MZ221683[a]	MZ352911[a]	MZ355232[a]	This study
	Cui 18302	MZ354955[a]	MZ355072[a]	–	MZ221684[a]	MZ352912[a]	MZ355233[a]	This study
	Cui 18317	MZ354956[a]	MZ355059[a]	–	MZ221685[a]	MZ352909[a]	MZ355285[a]	This study
	Cui 18326	MZ354957[a]	MZ355062[a]	–	MZ221686[a]	MZ352913[a]	MZ355244[a]	This study
G. oregonense	CBS 266.88	JQ781876	–	KJ143975	–	–	–	Cao *et al.* (2012), Zhou *et al.* (2015)
	CBS 265.88	JQ781875	–	KJ143974	KJ143933	–	–	Cao *et al.* (2012), Zhou *et al.* (2015)
G. parvulum	URM83345	JX310820	JX310834	–	–	–	–	De Lima Júnior *et al.* (2014)
	URM83344	JX310819	JX310833	–	–	–	–	De Lima Júnior *et al.* (2014)
G. pfeifferi	Dai 12153	MG279164	MZ355109[a]	–	MG367559	–	MZ355168[a]	Xing *et al.* (2018), this study
	Dai 12683	MG279165	MZ355108[a]	–	MG367560	–	–	Xing *et al.* (2018), this study
	CBS 221.48	–	MH867868	–	–	–	–	Unpublished
G. philippii	Cui 14443	MG279188	MZ355023[a]	MG367524	MG367578	MZ352871[a]	MZ355186[a]	Xing *et al.* (2018), this study
	Cui 14444	MG279189	MZ355022[a]	MG367525	MG367579	–	MZ355187[a]	Xing *et al.* (2018), this study
G. platense	BAFC384	AH008109	–	–	–	–	–	Gottlieb *et al.* (2000)
	BAFC2374	AH008110	–	–	–	–	–	Gottlieb *et al.* (2000)
G. podocarpense	QCAM 6422 (TYPE)	MF796661	MF796660	–	–	–	–	Crous *et al.* (2017b)
	JV 1504/126	MZ354942[a]	–	MZ345737[a]	MZ221687[a]	–	–	This study
G. polychromum	UMNOR3	MG654204	–	–	MG754744	–	–	Loyd *et al.* (2018)
	MS343OR	MG654197	–	–	MG754743	–	–	Loyd *et al.* (2018)
G. puerense	Dai 20427 (TYPE)	–	MZ355012[a]	MZ345738[a]	MZ221688[a]	MZ352884[a]	MZ355241[a]	This study
G. ravenelii	MS187FL	MG654211	–	MG754865	MG754745	–	–	Loyd *et al.* (2018)
	151FL	MG654208	–	–	–	–	–	Loyd *et al.* (2018)
G. resinaceum	MS1211	MT397406	–	–	MT415669	–	–	Náplavová *et al.* (2020)
	MS1212	MT397407	–	–	MT415670	–	–	Náplavová *et al.* (2020)
	LGAM 462	MG706250	MG706196	MG837821	MG837858	–	–	Unpublished
	LGAM 448	MG706249	MG706195	MG837820	MG837857	–	–	Unpublished

Table 1. (Continued).

Species	Voucher	GenBank accession No.						References
		ITS	nLSU	*rpb2*	*tef1*	mtSSU	nSSU	
G. ryvardenii	HKAS 58053 (TYPE)	HM138671	–	–	–	–	–	Kinge & Mih (2011)
	HKAS 58054	HM138672	–	–	–	–	–	Kinge & Mih (2011)
	HKAS 58055	HM138670	–	–	–	–	–	Kinge & Mih (2011)
G. sanduense	SA18012501 (TYPE)	MK345450	–	–	–	–	–	Hapuarachchi *et al.* (2019b)
	SA18012502	MK345451	–	–	–	–	–	Hapuarachchi *et al.* (2019b)
G. sessile	Dai 16403	MZ354934[a]	MZ355015[a]	MZ345739[a]	MZ221689[a]	MZ352907[a]	MZ355184[a]	This study
	JV 1209/27	KF605630	–	KJ143976	KJ143937	–	–	Zhou *et al.* (2015)
G. shanxiense	HSA 539	MK764269	–	MK789681	–	–	–	Liu *et al.* (2019)
	BJTC FM423 (TYPE)	MK764268	–	MK783940	MK783937	–	–	Liu *et al.* (2019)
	Cui 14565	MZ354908[a]	–	–	MZ221690[a]	–	MZ355245[a]	This study
	Dai 18921	MZ354909[a]	MZ355044[a]	MZ345740[a]	MZ221691[a]	–	MZ355320[a]	This study
G. sichuanense	HMAS42798 (TYPE)	JQ781877	–	–	–	–	–	Cao *et al.* (2012)
	Cui 16343	MZ354928[a]	MZ355011[a]	MZ345741[a]	MZ221692[a]	MZ352885[a]	MZ355171[a]	This study
	Dai 19651	MZ354929[a]	MZ355031[a]	MZ345742[a]	MZ221693[a]	MZ352889[a]	MZ355208[a]	This study
G. sinense	Cui 14526	MZ354961[a]	MZ355056[a]	MZ345743[a]	MZ221694[a]	–	MZ355189[a]	This study
	Cui 14461	MZ354963[a]	MZ355057[a]	MZ345744[a]	MZ221695[a]	–	MZ355190[a]	This study
	Dai 20079	MZ354962[a]	MZ355058[a]	MZ345745[a]	MZ221696[a]	–	MZ355284[a]	This study
Ganoderma sp.	N.1	MH806359	–	–	–	–	–	Le *et al.* (2018)
	N.3	MH806363	–	–	–	–	–	Le *et al.* (2018)
G. steyaertianum	6-WN-15(M)-A	KJ654459	–	–	–	–	–	Unpublished
	6-WN-16(M)-A	KJ654461	–	–	–	–	–	Unpublished
G. stipitatum	THC 16	KC884264	–	–	–	–	–	Unpublished
G. subangustisporum	Cui 18592 (TYPE)	MZ354981[a]	MZ355027[a]	–	MZ221697[a]	MZ352854[a]	–	This study
	Cui 18593	MZ354982[a]	MZ355028[a]	–	MZ221698[a]	MZ352852[a]	–	This study
	Cui 18596	MZ354983[a]	MZ355029[a]	–	MZ221699[a]	MZ352853[a]	–	This study
	Cui 18597	MZ354980[a]	MZ355025[a]	MZ345746[a]	MZ221700[a]	MZ352855[a]	MZ355216[a]	This study
G. subellipsoideum	Cui 18241	–	MZ355132[a]	–	MZ221701[a]	MZ352878[a]	–	This study
	Cui 18325 (TYPE)	–	MZ355134[a]	–	MZ221702[a]	–	MZ355295[a]	This study
	Cui 18327	–	MZ355133[a]	–	MZ221703[a]	MZ352859[a]	MZ355296[a]	This study
G. subflexipes	Cui 17247	MZ354921[a]	MZ355128[a]	MZ245395[a]	MZ221645[a]	–	MZ355140[a]	This study
	Cui 17257 (TYPE)	MZ354922[a]	MZ355129[a]	MZ245396[a]	MZ221646[a]	–	MZ355220[a]	This study

Table 1. (Continued).

Species	Voucher	GenBank accession No.						References
		ITS	nLSU	*rpb2*	*tef1*	mtSSU	nSSU	
	Cui 17258	–	MZ355130[a]	MZ245397[a]	MZ221647[a]	–	MZ355143[a]	This study
G. sublobatum	Cui 16804 (TYPE)	MZ354973[a]	–	MZ345747[a]	MZ221704[a]	MZ352879[a]	MZ355293[a]	This study
	Cui 16806	MZ354974[a]	MZ355034[a]	–	MZ221705[a]	MZ352918[a]	MZ355165[a]	This study
G. thailandicum	HKAS 104640 (TYPE)	MK848681	MK849879	MK875831	MK875829	–	–	Luangharn *et al.* (2019)
	HKAS 104641	MK848682	MK849880	MK875832	MK875830	–	–	Luangharn *et al.* (2019)
G. tongshanense	Cui 17168 (TYPE)	MZ354975[a]	MZ355024[a]	–	MZ221706[a]	–	MZ355206[a]	This study
G. tornatum	URM82776	JQ514110	JX310800	–	–	–	–	Unpublished
	TBG01AM2009	JQ514108	JX310808	–	–	–	–	Unpublished
G. tropicum	Dai 16434	MG279194	MZ355026[a]	MG367532	MG367585	MZ352872[a]	MZ355176[a]	Xing *et al.* (2018), this study
	Dai 19679	MZ354900[a]	MZ355009[a]	MZ358825[a]	MZ221707[a]	MZ352873[a]	MZ355222[a]	This study
	Dai 20029	MZ354902[a]	–	MZ358826[a]	MZ221708[a]	MZ352880[a]	MZ355225[a]	This study
	Dai 19491	MZ354901[a]	–	MZ358827[a]	MZ221709[a]	MZ352874[a]	MZ355141[a]	This study
G. tsugae	Cui 14110	MG279195	–	MG367533	MG367586	MZ352903[a]	MZ355192[a]	Xing *et al.* (2018), this study
	Cui 14112	MG279196	–	MG367534	MG367587	MZ352904[a]	MZ355193[a]	Xing *et al.* (2018), this study
G. tuberculosum	Dai 17412	MZ354943[a]	–	–	–	MZ352906[a]	MZ355199[a]	This study
	JV 1607/62	MZ354944[a]	MZ355087[a]	–	MZ221710[a]	MZ352875[a]	MZ355294[a]	This study
G. weberianum	Cui 16359	–	MZ355116[a]	MZ358828[a]	MZ221711[a]	MZ352886[a]	MZ355172[a]	This study
	CBS 219.36	MK603804	MH867289	MK611972	MK611974	–	–	Cabarroi-Hernández *et al.* (2019)
	CBS 128581	MK603805	MH876427	MK611971	MK636693	–	–	Cabarroi-Hernández *et al.* (2019)
	Dai 19673	MZ354930[a]	MZ355032[a]	MZ358829[a]	MZ221712[a]	MZ352890[a]	MZ355210[a]	This study
	Dai 19682	MZ354932[a]	MZ355042[a]	MZ358830[a]	MZ221713[a]	MZ352887[a]	MZ355213[a]	This study
	Dai 19689	MZ354931[a]	MZ355046[a]	–	MZ221714[a]	MZ352891[a]	MZ355226[a]	This study
G. weixiense	HKAS 100649 (TYPE)	MK302444	MK302446	–	MK302442	–	–	Ye *et al.* (2019)
	HKAS 100650	MK302445	MK302447	–	MK302443	–	–	Ye *et al.* (2019)
G. wiiroense	UMN-20-GHA	KT952361	KT952362	–	–	–	–	Crous *et al.* (2015)
	MIN 938704 (TYPE)	KT952363	KT952364	–	–	–	–	Crous *et al.* (2015)
G. williamsianum	Dai 17790	MZ354947[a]	MZ355060[a]	–	MZ221715[a]	–	MZ355182[a]	This study
	Dai 16809	MG279183	MZ355030[a]	MG367535	MG367588	–	MZ355183[a]	Xing *et al.* (2018), this study
	Dai 20553	MZ354948[a]	MZ355061[a]	MZ358831[a]	MZ221716[a]	–	MZ355242[a]	This study
	Dai 19611	MZ354949[a]	MZ355048[a]	MZ358832[a]	MZ221717[a]	–	–	This study
G. yunlingense	Cui 16288 (TYPE)	MZ354915[a]	MZ355077[a]	–	MZ221718[a]	–	MZ355179[a]	This study

Table 1. (Continued).

Species	Voucher	GenBank accession No.						References
		ITS	nLSU	*rpb2*	*tef1*	mtSSU	nSSU	
	Cui 17043	MZ354916[a]	MZ355078[a]	–	MZ221719[a]	–	MZ355228[a]	This study
	Cui 17958	MZ354917[a]	–	–	–	–	–	This study
G. zonatum	FL-03	KJ143922	–	KJ143980	KJ143942	–	–	Zhou *et al.* (2015)
	FL-02	KJ143921	–	KJ143979	KJ143941	–	–	Zhou *et al.* (2015)
Haddowia longipes	LPDR17072708	MK345423	MK346828	–	–	–	MK346836	Hapuarachchi *et al.* (2019b)
	LPDR17072709	MK345424	MK346829	–	–	–	MK346837	Hapuarachchi *et al.* (2019b)
Ha. macropora	JV 1908/46 (TYPE)	MZ354870[a]	MZ354998[a]	MZ358847[a]	MZ221720[a]	MZ352923[a]	MZ355251[a]	This study
Magoderna subresinosum	Dai 18626	MK119823	MK119902	MK121507	MK121571	MZ352831[a]	MZ355211[a]	Sun *et al.* (2020), this study
	Cui 18262	MZ354871[a]	MZ355088[a]	–	–	MZ352832[a]	MZ355258[a]	This study
	Cui 18280	MZ354872[a]	MZ355095[a]	–	MZ221721[a]	MZ352833[a]	MZ355304[a]	This study
Neoganoderma neurospora	DHCR559	MN077531	–	–	–	–	–	Costa-Rezende *et al.* (2020b)
	GAS1013	MN077532	–	–	–	–	–	Costa-Rezende *et al.* (2020b)
Sanguinoderma bataanense	Cui 6285	MK119831	MK119910	MK121537	MK121580	MZ352793[a]	MZ355238[a]	Sun *et al.* (2020), this study
	Dai 10746	MK119832	MK119911	MK121511	MK121581	MZ352801[a]	MZ355267[a]	Sun *et al.* (2020), this study
	Zhou 153	KJ531657	–	–	–	–	–	Li & Yuan (2015)
	Dai 7862	KJ531658	–	–	–	–	–	Li & Yuan (2015)
Sa. elmerianum	Cui 8940	MK119833	MK119912	–	–	MZ352812[a]	MZ355305[a]	Sun *et al.* (2020), this study
	HMAS 133187	MK119834	MK119913	–	–	MZ352824[a]	MZ355234[a]	Sun *et al.* (2020), this study
	Cui 18234	MZ354873[a]	MZ355080[a]	–	MZ221722[a]	MZ352814[a]	MZ355236[a]	This study
	Dai 20503	MZ354874[a]	MZ355081[a]	–	MZ221723[a]	MZ352813[a]	MZ355154[a]	This study
	Dai 20634	MZ354875[a]	MZ355082[a]	–	MZ221724[a]	MZ352821[a]	MZ355148[a]	This study
Sa. flavovirens	Cui 16935 (TYPE)	–	MK119914	MK121532	MK121582	MZ352811[a]	MZ355254[a]	Sun *et al.* (2020), this study
Sa. guangdongense	Dai 16724	MZ354876[a]	MZ355117[a]	MZ358833[a]	MZ221725[a]	MZ352815[a]	MZ355271[a]	This study
	Cui 17259 (TYPE)	MZ354877[a]	MZ355123[a]	MZ358834[a]	MZ221726[a]	MZ352816[a]	MZ355139[a]	This study
	Dai 20419	MZ354890[a]	MZ355083[a]	MZ358835[a]	MZ221727[a]	MZ352818[a]	MZ355155[a]	This study
	Cui 17240	–	MZ355124[a]	MZ358836[a]	MZ221728[a]	MZ352817[a]	MZ355287[a]	This study
Sa. infundibulare	Dai 18148	MK119846	MK119925	MK121528	MK121596	MZ352789[a]	MZ355259[a]	Sun *et al.* (2020), this study
	Dai 18149	MK119847	MK119926	MK121529	MK121597	MZ352790[a]	MZ355239[a]	Sun *et al.* (2020), this study
	Cui 17238	OM780277	–	MZ358837[a]	MZ221729[a]	MZ352800[a]	MZ355149[a]	This study
	Cui 17248 (TYPE)	MZ354880[a]	MZ355125[a]	–	MZ221730[a]	MZ352787[a]	MZ355150[a]	This study
	Dai 18151	MK119848	–	MK121530	MK121598	MZ352788[a]	MZ355274[a]	Sun *et al.* (2020), this study

Table 1. (Continued).

Species	Voucher	GenBank accession No.						References
		ITS	nLSU	*rpb2*	*tef1*	mtSSU	nSSU	
	Cui 17256	MZ354885[a]	–	MZ358838[a]	MZ221731[a]	MZ352791[a]	MZ355144[a]	This study
	URM 450213	MK119849	MK119927	–	–	MZ352792[a]	MZ355252[a]	Sun *et al.* (2020), this study
Sa. laceratum	Cui 8155 (TYPE)	MK119851	MK119928	–	–	MZ352810[a]	–	Sun *et al.* (2020), this study
	A5	MG383652	–	–	–	–	–	Unpublished
Sa. longistipitum	Dai 20696 (TYPE)	MZ354881[a]	MZ355084[a]	–	MZ221732[a]	MZ352822[a]	MZ355145[a]	This study
	Cui 13903	MZ354882[a]	MZ355114[a]	MZ358839[a]	MZ221733[a]	MZ352809[a]	MZ355301[a]	This study
	Dai 13891	MZ354886[a]	MZ355126[a]	–	–	MZ352834[a]	MZ355325[a]	This study
	Dai 16635	MZ354883[a]	MZ355120[a]	MZ358840[a]	MZ221734[a]	MZ352802[a]	MZ355260[a]	This study
Sa. melanocarpum	Dai 18512	MZ354888[a]	MZ355118[a]	–	MZ221735[a]	MZ352794[a]	MZ355313[a]	This study
	Dai 18603 (TYPE)	MZ354889[a]	MZ355113[a]	MZ358841[a]	MZ221736[a]	MZ352796[a]	MZ355281[a]	This study
Sa. microporum	Cui 13851 (TYPE)	MK119854	MK119933	MK121512	MK121602	MZ352797[a]	MZ355270[a]	Sun *et al.* (2020), this study
	Cui 18270	–	MZ355086[a]	–	–	MZ352808[a]	MZ355235[a]	This study
	Cui 14022	MK119856	MK119935	MK121515	MK121604	MZ352798[a]	MZ355298[a]	Sun *et al.* (2020), this study
Sa. microsporum	Dai 16726 (TYPE)	–	MZ355119[a]	–	MZ221737[a]	MZ352795[a]	MZ355272[a]	This study
	Cui 13901	MZ354879[a]	MZ355121[a]	–	MZ221738[a]	MZ352803[a]	MZ355299[a]	This study
	Cui 13897	MZ354878[a]	MZ355127[a]	–	MZ221739[a]	MZ352804[a]	MZ355300[a]	This study
Sa. perplexum	Cui 6496	KJ531650	KU220001	MK121538	MK121583	MZ352825[a]	MZ355263[a]	Li & Yuan (2015), this study
	Cui 6554	MK119835	MK119915	MK121540	MK121585	MZ352826[a]	MZ355264[a]	Sun *et al.* (2020), this study
	Wei 5562	KJ531652	–	–	–	–	–	Li & Yuan (2015)
	Dai 10811	KJ531651	KU220002	MK121539	MK121584	MZ352827[a]	MZ355302[a]	Li & Yuan (2015), this study
Sa. reniforme	Cui 16511 (TYPE)	MK119850	MK119929	MK121531	MK121599	–	MZ355322[a]	Sun *et al.* (2020), this study
Sa. rude	Cui 16592	MK119836	MK119916	MK121521	MK121586	MZ352924[a]	MZ355307[a]	Sun *et al.* (2020), this study
	DHCR457	MN077517	MN077551	–	MN061693	–	–	Costa-Rezende *et al.* (2020b)
	MEL 2317411	MK119842	–	MK121524	MK121592	MZ352819[a]	MZ355306[a]	Sun *et al.* (2020), this study
Sa. rugosum	Cui 8795	MK119843	MK119922	MK121516	MK121593	MZ352799[a]	MZ355266[a]	Sun *et al.* (2020), this study
	Cui 9011	KJ531664	KU220010	MK121517	KU572504	MZ352805[a]	MZ355237[a]	Li & Yuan (2015), this study
	Cui 9066	MZ354884[a]	MZ355122[a]	–	MZ221740[a]	MZ352806[a]	MZ355268[a]	This study
	Dai 20582	MZ354887[a]	MZ355085[a]	MZ358842[a]	MZ221741[a]	MZ352823[a]	MZ355156[a]	This study
	Cui 9012	KJ531665	KU220011	MK121518	KU572503	MZ352807[a]	MZ355269[a]	Li & Yuan (2015), this study
Sa. sinuosum	MEL 2366586	MK119852	MK119930	MK121527	MK121600	MZ352920[a]	MZ355261[a]	Sun *et al.* (2020), this study
	MEL 2341763 (TYPE)	MK119853	MK119931	MK121525	MK121601	MZ352820[a]	MZ355291[a]	Sun *et al.* (2020), this study

Table 1. (Continued).

Species	Voucher	GenBank accession No.						References
		ITS	nLSU	*rpb2*	*tef1*	mtSSU	nSSU	
Sa. tricolor	Cui 18292 (TYPE)	–	MZ355101[a]	–	MZ221742[a]	MZ352828[a]	MZ355273[a]	This study
	Cui 18242	MZ354992[a]	MZ355099[a]	MZ358843[a]	MZ221743[a]	MZ352829[a]	MZ355303[a]	This study
	Dai 18574	MZ354993[a]	MZ355102[a]	MZ358844[a]	MZ221744[a]	MZ352830[a]	MZ355265[a]	This study
Sinoganoderma shandongense	Dai 15785	MG279190	MZ355052[a]	MG367526	MG367580	MZ352900[a]	MZ355200[a]	Xing *et al.* (2018), this study
	Dai 15787	MG279191	MZ355053[a]	MG367527	MG367581	MZ352901[a]	MZ355201[a]	Xing *et al.* (2018), this study
	Dai 15791	MG279192	MZ355054[a]	MG367528	MG367582	MZ352902[a]	MZ355323[a]	Xing *et al.* (2018), this study
	Dai 20243	–	MZ355055[a]	–	MZ221745[a]	–	–	This study
	Dai 20244	MZ354938[a]	MZ355073[a]	–	MZ221746[a]	–	–	This study
	xsd08032	EU918700	–	–	–	–	–	Unpublished
	xsd08085	FJ478127	–	–	–	–	–	Unpublished
Tomophagus cattienensis	CT119	JN184398	–	–	–	–	–	Le *et al.* (2012)
	CT99 (TYPE)	JN184397	–	–	–	–	–	Le *et al.* (2012)
	Dai 18487	MZ354988[a]	–	MZ358845[a]	MZ221747[a]	MZ352898[a]	MZ355212[a]	This study
To. colossus	URM80450	JX310825	JX310839	–	–	–	–	De Lima Júnior *et al.* (2014)
	URM83330	JQ618247	JX310811	–	–	–	–	De Lima Júnior *et al.* (2014)
Trachydermella tsunodae	GR363	FJ154773	–	–	–	–	–	Unpublished
	WD2034	AB588989	AB368069	AB368127	–	–	–	Sotome *et al.* (2011)
Perenniporia subtephropora	Dai 10962 (TYPE)	JQ861752	JQ861768	KX880850	KF286329	KF218323	–	Zhao & Cui (2013)
	Dai 10964	JQ861753	JQ861769	KX880851	KF286330	KF218324	–	Zhao & Cui (2013)

[a] Newly generated sequences for this study.

RESULTS

Molecular phylogeny

In this study, 1 382 sequences derived from six gene loci (ITS, nLSU, *rpb2*, *tef1*, mtSSU and nSSU) were used to reconstruct phylogenetic trees of *Ganodermataceae*, including 374 sequences of ITS, 242 sequences of nLSU, 173 sequences of *rpb2*, 242 sequences of *tef1*, 158 sequences of mtSSU and 193 sequences of nSSU. The combined six-gene dataset (ITS + nLSU + *rpb2* + *tef1* + mtSSU + nSSU) included sequences from 391 specimens representing 146 taxa from *Ganodermataceae* and *Perenniporia subtephropora* as the outgroup. The partition homogeneity test indicated all the six different genes displayed a congruent phylogenetic signal (P value = 1.00). The best-fit evolutionary models selected by MrModeltest v. 2.3 for each region of the six genes were GTR + I + G (ITS1), K80 (5.8S), HKY + I + G (ITS2), GTR + I + G (nLSU), K80 + I + G (*rpb2* introns), K80 + G (*rpb2* 1st codon), GTR + I + G (*rpb2* 2nd codon), GTR + I + G (*tef1* introns), HKY + I + G (*tef1* 1st codon), SYM + I + G (*tef1* 2nd codon), SYM + I + G (*tef1* 3rd codon), GTR + I + G (mtSSU) and GTR + I + G (nSSU). These models were applied in Bayesian analyses for the combined dataset.

The combined six-gene dataset has an aligned length of 5 172 total characters including gaps, of which 3 780 are constant, 197 are variable and parsimony-uninformative, and 1 195 are parsimony-informative. The average standard deviation of split frequencies in the Bayesian analyses reached 0.008329. The calculated values based on the combined six-gene dataset are shown in Fig. 1. Thirteen clades were obtained in the phylogenetic analyses of *Ganodermataceae*: *Amauroderma* clade (100 % ML, 1.00 BPP), *Amaurodermellus* clade (100 % ML, 1.00 BPP), *Cristataspora* clade (100 % ML, 1.00 BPP), *Foraminispora* clade (99 % ML, 1.00 BPP), *Furtadoella gen. nov.* clade (100 % ML, 1.00 BPP), *Ganoderma* clade (58 % ML), *Haddowia* clade (85 % ML, 0.99 BPP), *Magoderna* clade (100 % ML, 1.00 BPP), *Neoganoderma gen. nov.* clade (100 % ML, 1.00 BPP), *Sanguinoderma* clade (88 % ML, 0.98 BPP), *Sinoganoderma gen. nov.* clade (100 % ML, 1.00 BPP), *Tomophagus* clade (100 % ML, 1.00 BPP) and *Trachydermella gen. nov.* clade (100 % ML, 1.00 BPP)

The *Ganoderma* clade is composed of 95 taxa including 16 new species. All taxa in this clade were divided into two groups according to laccate or dull pileal surface, and 10 subclades are separated by this feature: subclade I-laccate/dull (84 % ML, 1.00 BPP), subclade II-laccate (100 % ML, 1.00 BPP), subclade III-laccate (100 % ML, 1.00 BPP), subclade IV-dull (100 % ML, 1.00 BPP), subclade V-laccate/dull (93 % ML, 1.00 BPP), subclade VI-dull (98 % ML, 1.00 BPP), subclade VII-laccate/dull (75 % ML, 0.99 BPP), subclade VIII, subclade IX (100 % ML, 1.00 BPP) and subclade X (99 % ML, 1.00 BPP), these subclades were shown in Fig. 1.

The phylogenetic topologies of *Ganodermataceae* based on ITS, nLSU, *rpb2*, *tef1*, mtSSU and nSSU sequences respectively with ML bootstrap support values ≥ 50 % are shown in Figs 2–7. Besides, including *Perenniporia subtephropora* as outgroup, there were 146 taxa included in the ITS dataset, 107 taxa included in the nLSU dataset, 87 taxa included in the *rpb2* dataset, 102 taxa included in the *tef1* dataset, 70 taxa included in the mtSSU dataset, and 81 taxa included in the nSSU dataset.

Taxonomy

Ganodermataceae Donk, Bull. Bot. Gdns Buitenz. 17: 474. 1948. Fig. 8. MycoBank MB 80782.

Type genus: *Ganoderma* P. Karst.

Description: *Basidiomata* annual to perennial, sessile to stipitate, pileate, fleshy to woody hard. *Pilei* variable in shape and colour, with or without laccate surface. *Hyphal system* dimitic to trimitic, rarely monomitic in context; generative hyphae mostly bearing clamp connections, rarely simple-septate. *Basidiospores* subglobose to ovoid or reniform, truncated or not, double-walled and slightly to distinctly thick-walled with varied ornamentation.

Notes: In this study, 12 genera of *Ganodermataceae*: *Amauroderma*, *Amaurodermellus*, *Cristataspora*, *Foraminispora*, *Furtadoella*, *Ganoderma*, *Haddowia*, *Humphreya*, *Magoderna*, *Sanguinoderma*, *Tomophagus*, *Trachydermella* and two new genera: *Neoganoderma* and *Sinoganoderma* were confirmed based on morphological and molecular studies. *Humphreya* was not included in the phylogenetic analyses since there are no available specimens to obtain sequences, but it is treated as an independent genus within *Ganodermataceae* based on its unique basidiospore ornamentation.

Key to accepted genera of *Ganodermataceae*

1a. Colour of fresh pore surface becoming blood red when bruised ..... *Sanguinoderma*
1b. Colour of fresh pore surface darkening or unchanged when bruised 2

2a. Basidiospores non-truncated 3
2b. Basidiospores truncated 8

3a. Hyphal system monomitic in context, generative hyphae clamped to simple-septate ..... *Furtadoella*
3b. Hyphal system di-trimitic in context, generative hyphae clamped 4

4a. Exospore wall incomplete and smooth, endospore wall with two longitudinal crests and transverse membranes ..... *Haddowia*
4b. Exospore wall complete and uneven to foveolate or verrucose, endospore wall with obvious spinules 5

5a. Endospore wall with hollow spinules which persist until exospore wall forming holes ..... *Foraminispora*
5b. Endospore wall with solid spinules, exospore wall verrucose 6

6a. Basidiospores globose to oblong ..... *Amauroderma*
6b. Basidiospores ellipsoid to ovoid 7

7a. Basidiomata woody hard, with short stipe or sessile ..... *Magoderna*
7b. Basidiomata corky, with long stipe ..... *Amaurodermellus*

8a. Basidiomata soft to fleshy when fresh 9
8b. Basidiomata soft corky to woody hard when fresh 10

9a. Hyphal system dimitic, generative hyphae branched ..... *Tomophagus*
9b. Hyphal system trimitic, generative hyphae unbranched ..... *Trachydermella*

10a. Endospore wall with spiny ornamentation 11
10b. Endospore wall with ridged ornamentation 12

11a. Pore dissepiments thin, context cream; exospore wall uneven to foveolate ..... *Sinoganoderma*
11b. Pore dissepiments thick, context pale white to dark brown; exospore wall verrucose to vermicular ..... *Ganoderma*

12a. Basidiomata sessile to subsessile; basidiospores inconspicuously truncated ..... *Neoganoderma*
12b. Basidiomata stipitate; basidiospores conspicuously truncated 13

13a. Context white; endospore wall with vertical or transverse ridges ..... *Cristataspora*
13b. Context honey; endospore wall with reticular ridges ..... *Humphreya*

Amauroderma Murrill, Bull. Torrey Bot. Club 32: 366. 1905. MycoBank MB 17052.

Type species: *Amauroderma schomburgkii* (Mont. & Berk.) Torrend.

For a detailed description of *Amauroderma*, see Costa-Rezende *et al.* (2016) and Sun *et al.* (2020).

Notes: The *Amauroderma* clade is composed of species from the Neotropics. According to Costa-Rezende *et al.* (2020a), 24 species of *Amauroderma* have been recorded from the Neotropics, 16 species with available DNA sequences were included in the current phylogenetic analyses. Besides these species, this genus contains 40 taxa which have been recorded from Africa, Southeast Asia and Central America, and the sequences of these taxa are not available. Until now, 58 species (Table 2) can be recognised in *Amauroderma* based on previous literature (Furtado 1967b, Steyaert 1972, Corner 1983, Henao-M 1997, Moncalvo & Ryvarden 1997, Gulaid & Ryvarden 1998, Aime *et al.* 2003, Ryvarden 2004b, Gomes-Silva *et al.* 2015, Ryvarden 2020).

Amaurodermellus Costa-Rezende *et al.*, Mycol. Prog. 19: 727. 2020. MycoBank MB 833561.

Type species: *Amaurodermellus ovisporum* (Gomes-Silva *et al.*) Costa-Rezende *et al.*

For a detailed description of *Amaurodermellus*, see Costa-Rezende *et al.* (2020b).

Notes: *Amaurodermellus* was established by Costa-Rezende *et al.* (2020b) with type species, *Amaurodermellus ovisporum*. It can be distinguished from the other genera in *Ganodermataceae* by ovoid basidiospores with inconspicuous spinules on the endospore wall. Several species in *Ganoderma* also have ovoid basidiospores such as *G. sichuanense*, but *Amaurodermellus ovisporum* has a dark dull pileal surface and non-truncated basidiospores which is similar to *Amauroderma*. In this study, the taxonomic status of *Amaurodermellus* was further confirmed by multi-gene based phylogenetic analyses (Fig. 1).

Cristataspora Robledo & Costa-Rezende, Mycol. Prog. 19: 733. 2020. MycoBank MB 833558.

Type species: *Cristataspora coffeata* (Berk.) Robledo *et al.*

For a detailed description of *Cristataspora*, see Costa-Rezende *et al.* (2020b).

Notes: *Cristataspora coffeata* as the only species in *Cristataspora* was previously placed in *Humphreya* due to the reticulate or disjointed crests on the endospore wall (Steyaert 1972). Costa-Rezende *et al.* (2020b) examined the specimens of *C. coffeata* collected from neotropical areas, and the vertical or transverse ridges on the endospore wall observed under SEM rendered it distinct from *Humphreya*. Therefore, *Cristataspora* was established as a new genus based on its different basidiospores and independent clade in the phylogenetic analysis (Fig. 1).

Foraminispora Robledo *et al.*, Persoonia 39: 258. 2017. MycoBank MB 819015.

Type species: *Foraminispora rugosa* (Berk.) Costa-Rezende *et al*.

For a detailed description of *Foraminispora*, see Costa-Rezende *et al.* (2017) and Sun *et al.* (2020).

Notes: *Foraminispora* is characterised by the unique ultrastructure of its basidiospores, which shows an uneven exospore wall with holes caused by hollow and columnar spinules on the endospore wall. In this study, *Foraminispora* is recognised as an independent clade including five species with high support (Fig. 1). Species of this genus were reported from East Asia and Neotropics, and the descriptions of these species can be found in Costa-Rezende *et al.* (2017) and Sun *et al.* (2020).

Furtadoella B.K. Cui & Y.F. Sun, ***gen. nov.*** MycoBank MB 840977.

Diagnosis: Differs from other genera by its soft basidiomata, white context, monomitic hyphal system in context, with both clamped and simple-septate generative hyphae.

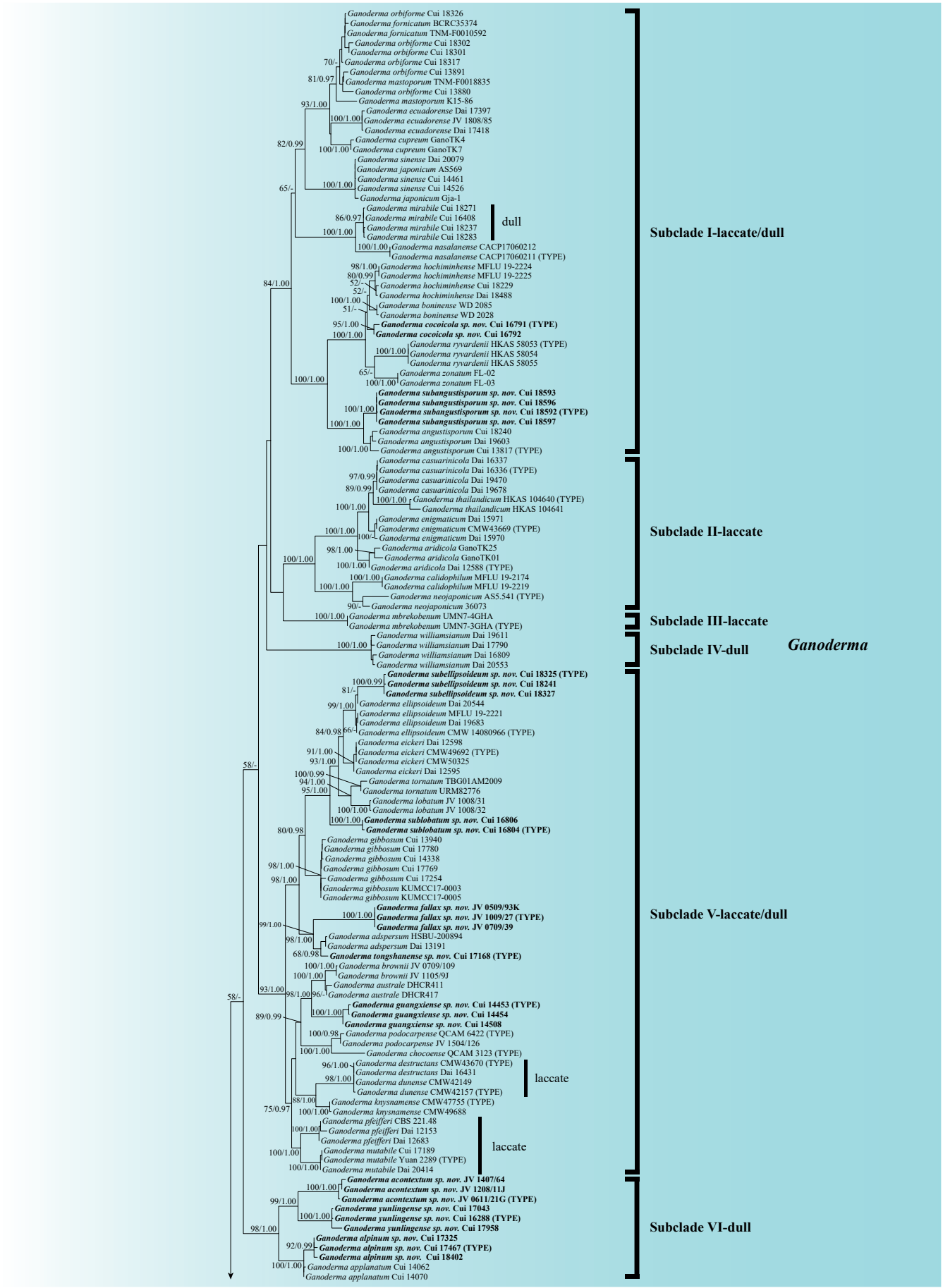

Fig. 1. Maximum Likelihood analyses of *Ganodermataceae* based on dataset of ITS + nLSU + *rpb2* + *tef1* + mtSSU + nSSU. Maximum Likelihood bootstrap values higher than 50 % and Bayesian posterior probabilities values more than 0.95 are shown. New species are in bold. *Ganoderma* clade is divided by laccate or dull pileal surface.

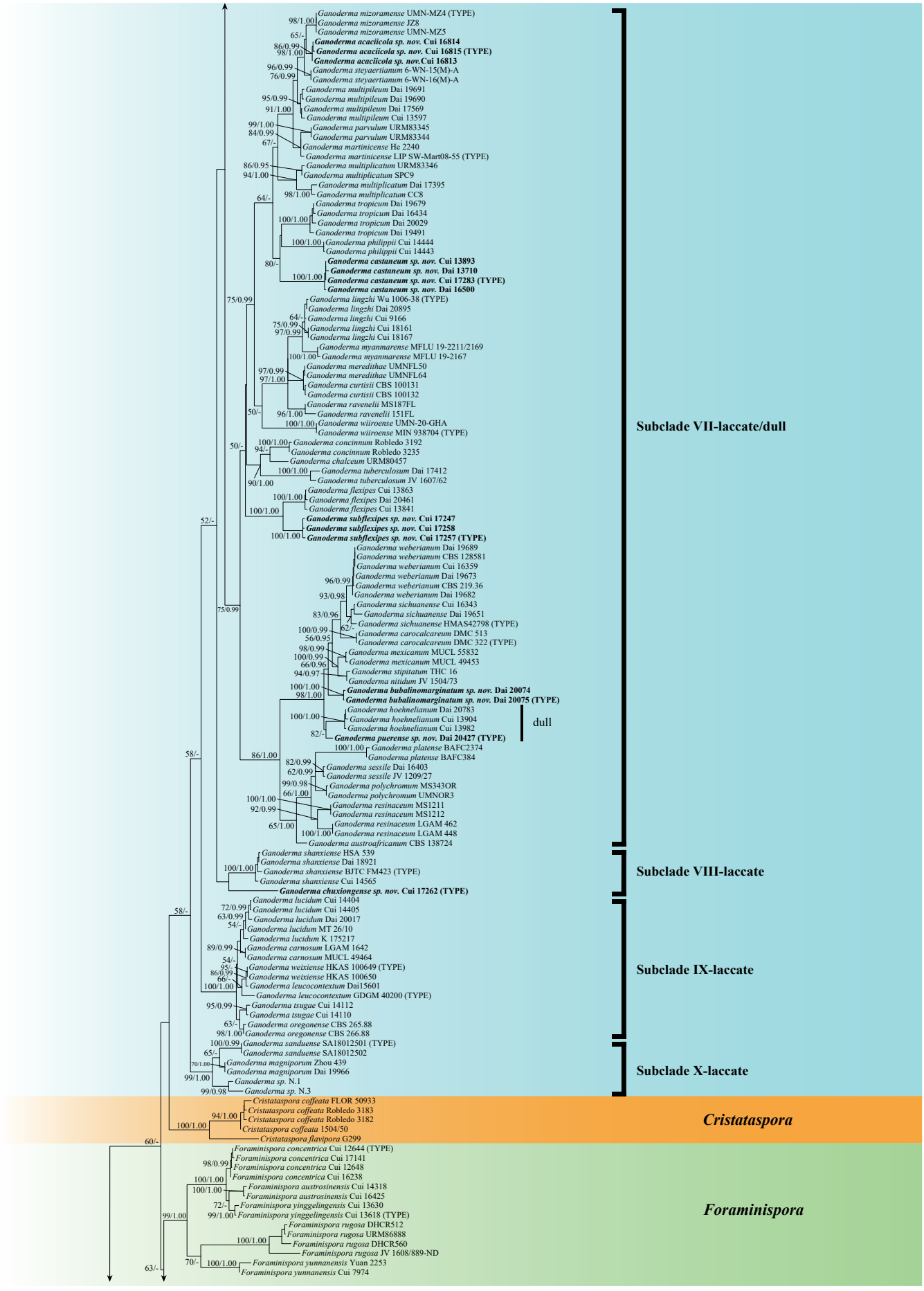

Fig. 1. (Continued).

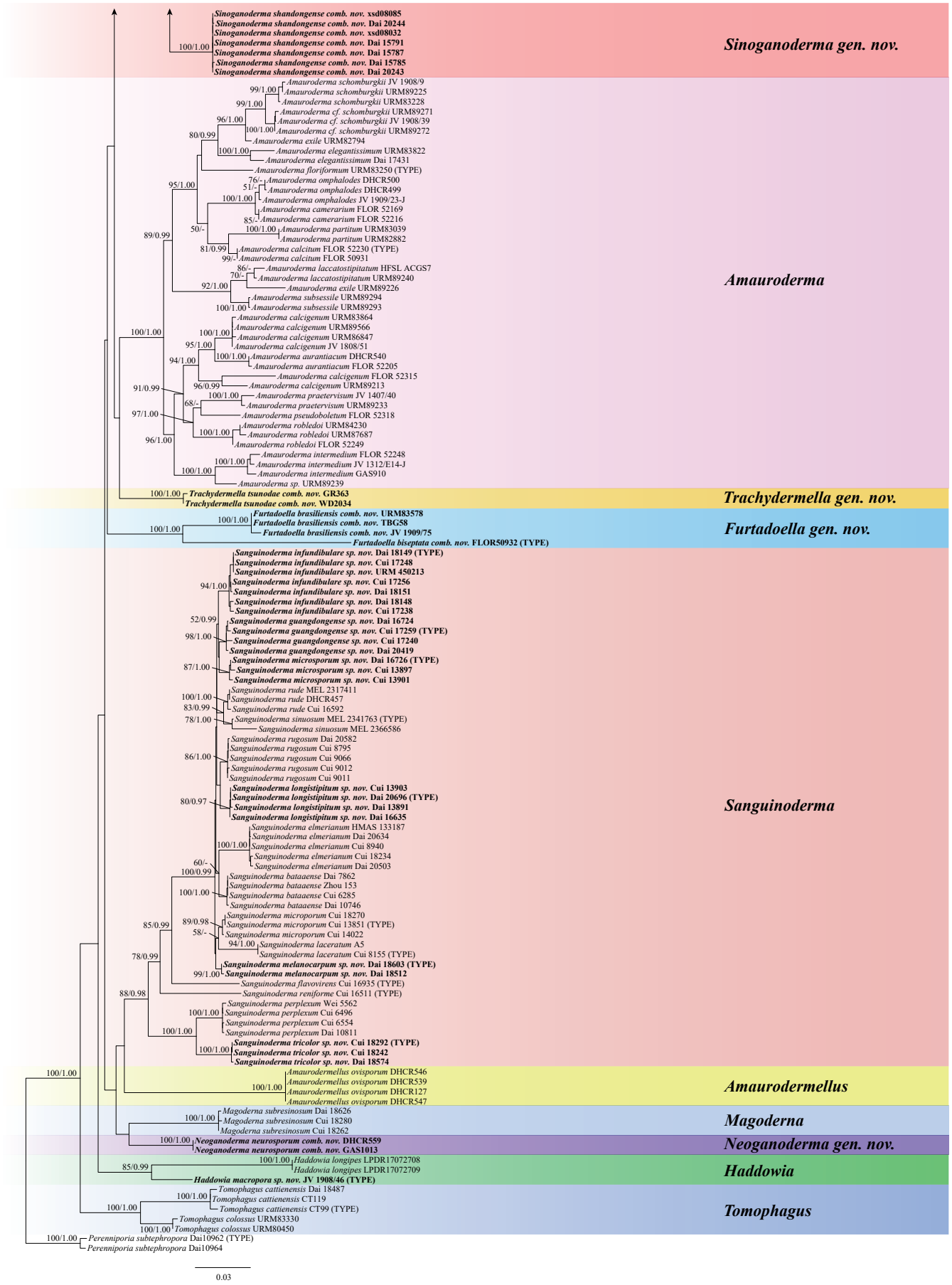

Fig. 1. (Continued).

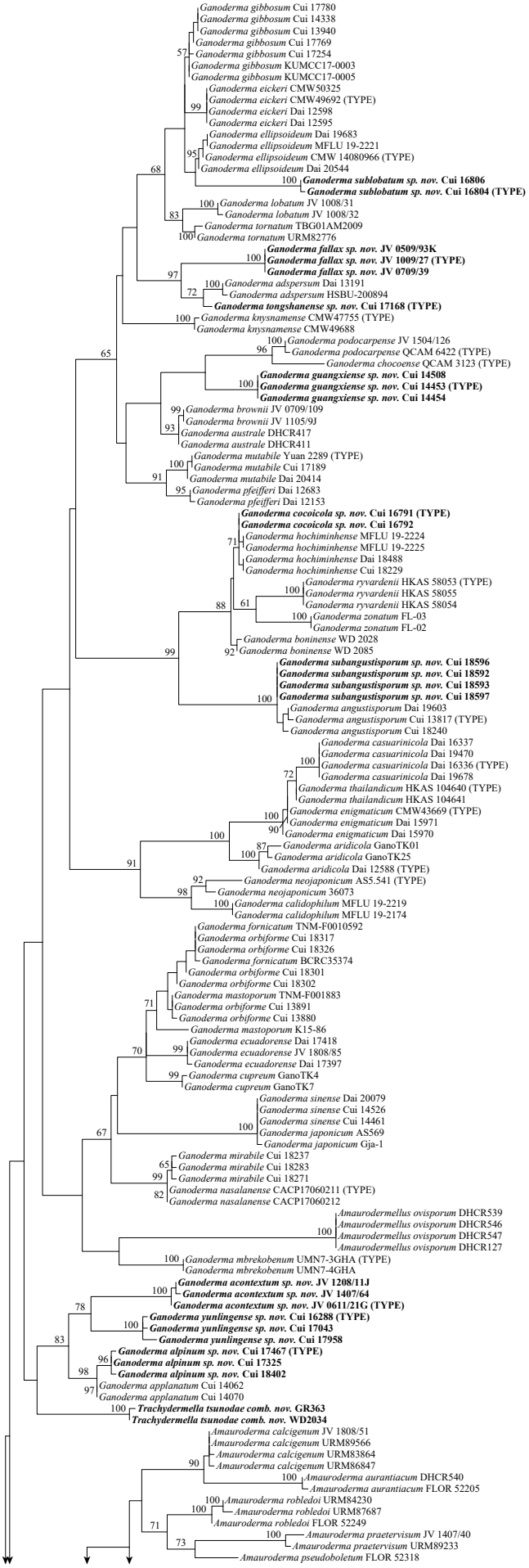

Fig. 2. Maximum Likelihood analyses of *Ganodermataceae* based on dataset of ITS. Maximum Likelihood bootstrap values higher than 50 % are shown. New species are in bold.

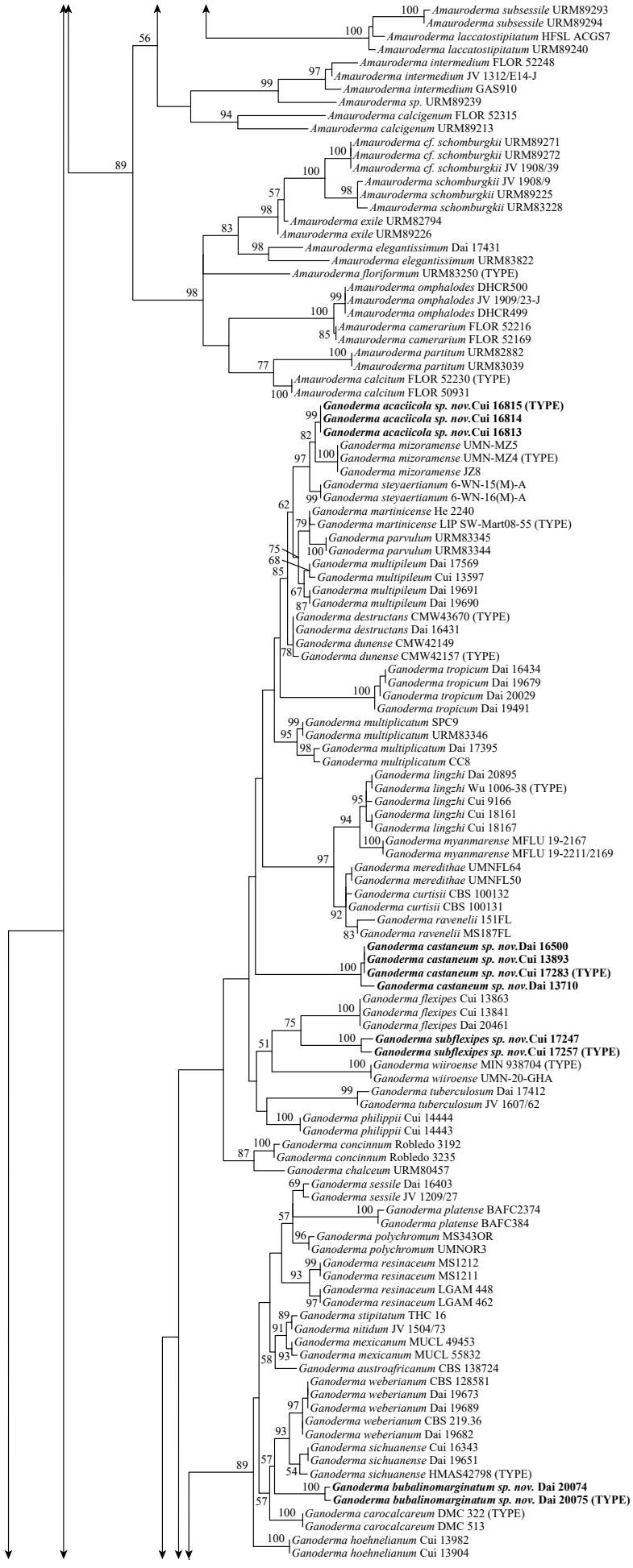

Fig. 2. (Continued).

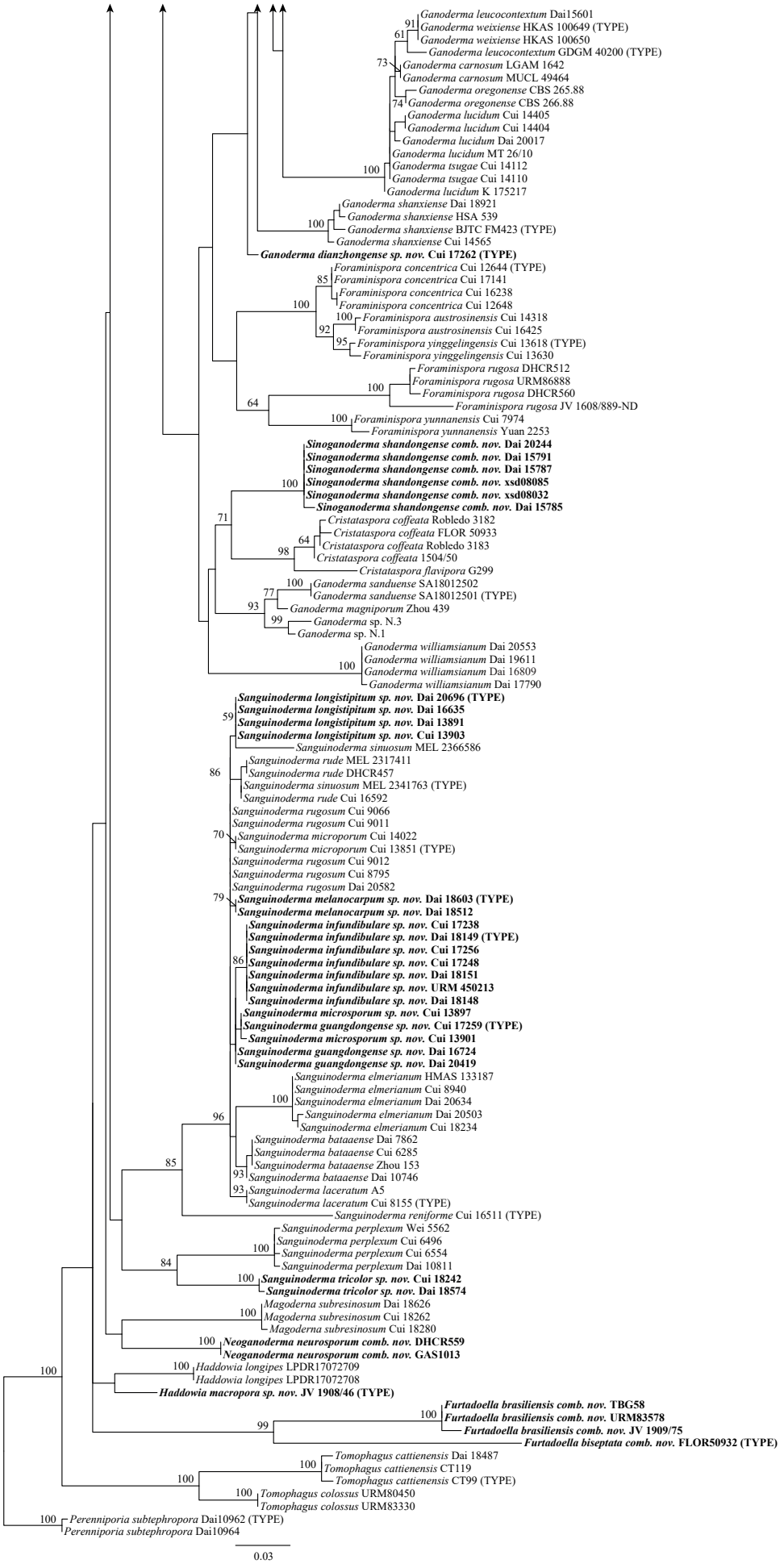

Fig. 2. (Continued).

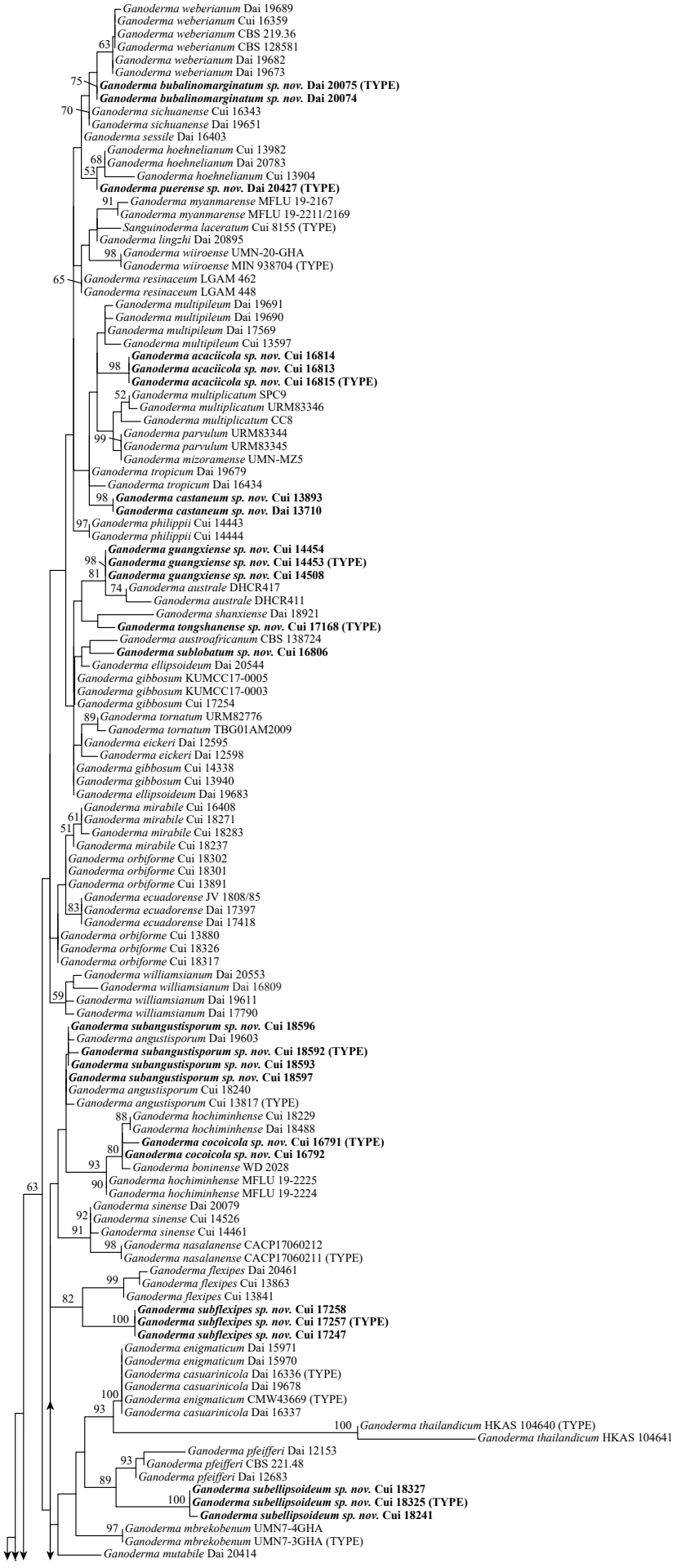

Fig. 3. Maximum Likelihood analyses of *Ganodermataceae* based on dataset of nLSU. Maximum Likelihood bootstrap values higher than 50 % are shown. New species are in bold.

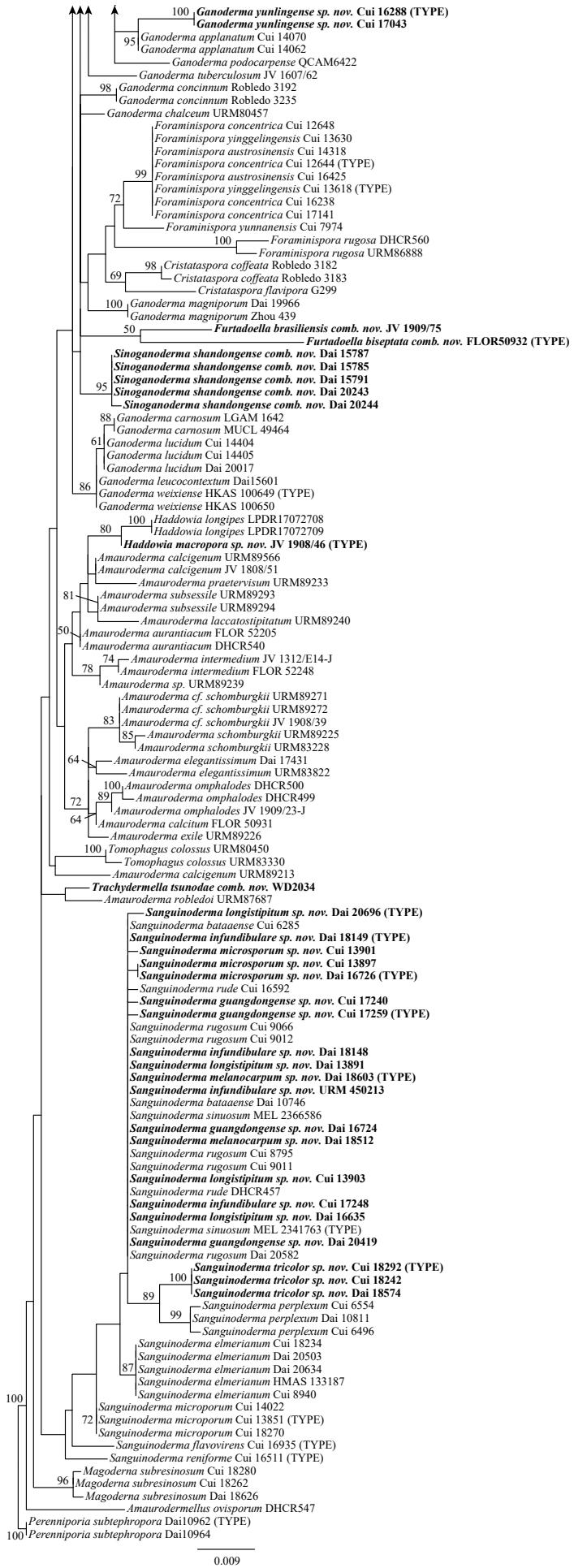

Fig. 3. (Continued).

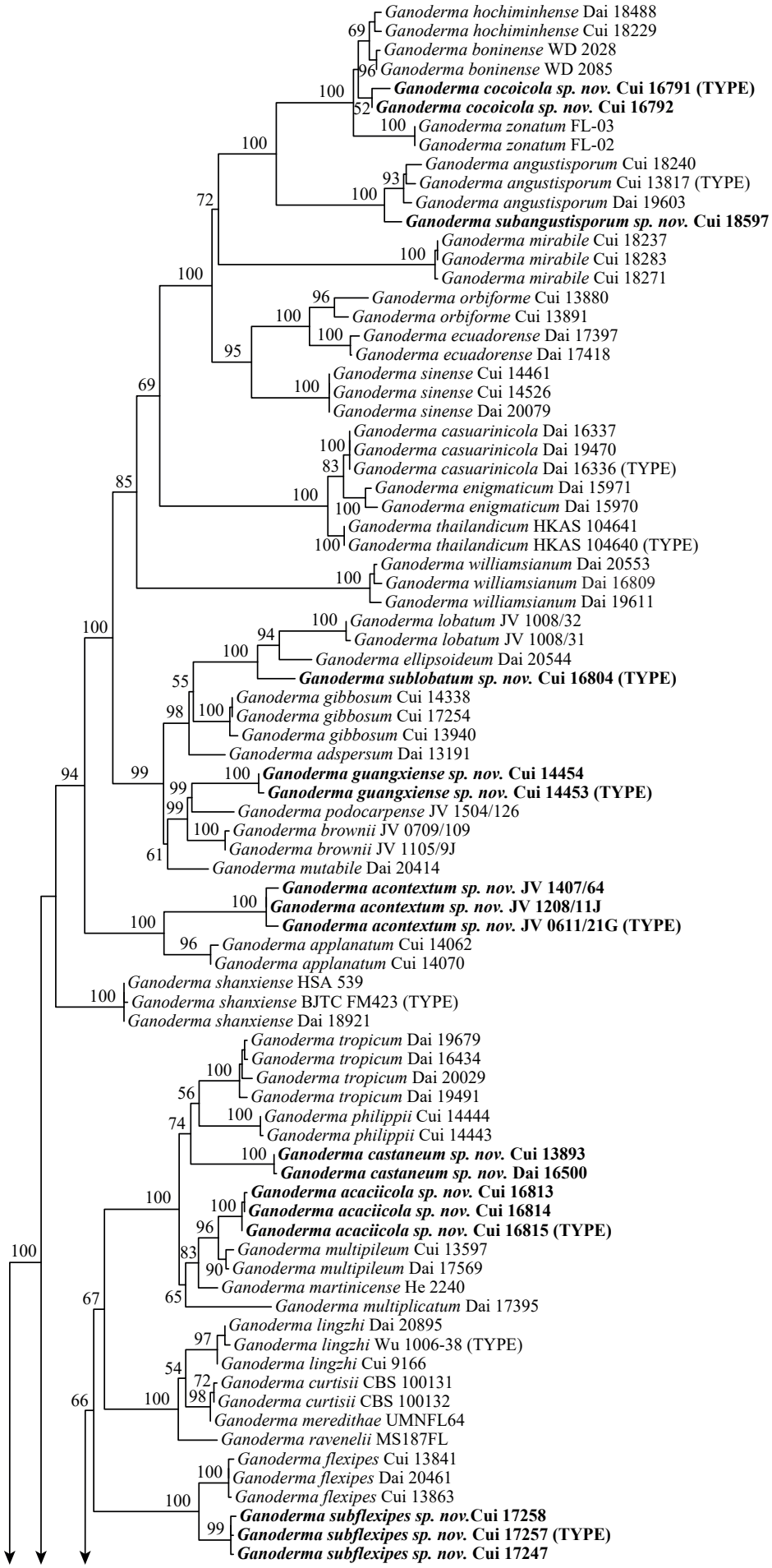

Fig. 4. Maximum Likelihood analyses of *Ganodermataceae* based on dataset of *rpb2*. Maximum Likelihood bootstrap values higher than 50 % are shown. New species are in bold.

Fig. 4. (Continued).

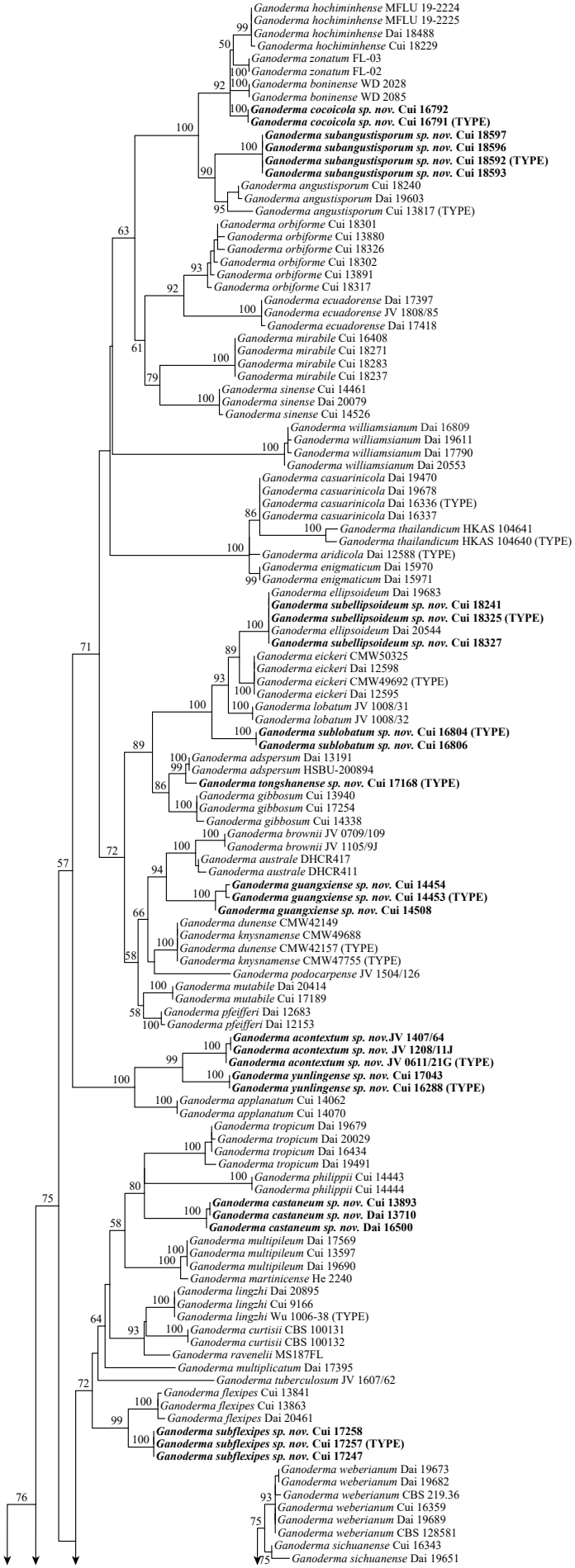

Fig. 5. Maximum Likelihood analyses of *Ganodermataceae* based on dataset of *tef1*. Maximum Likelihood bootstrap values higher than 50 % are shown. New species are in bold.

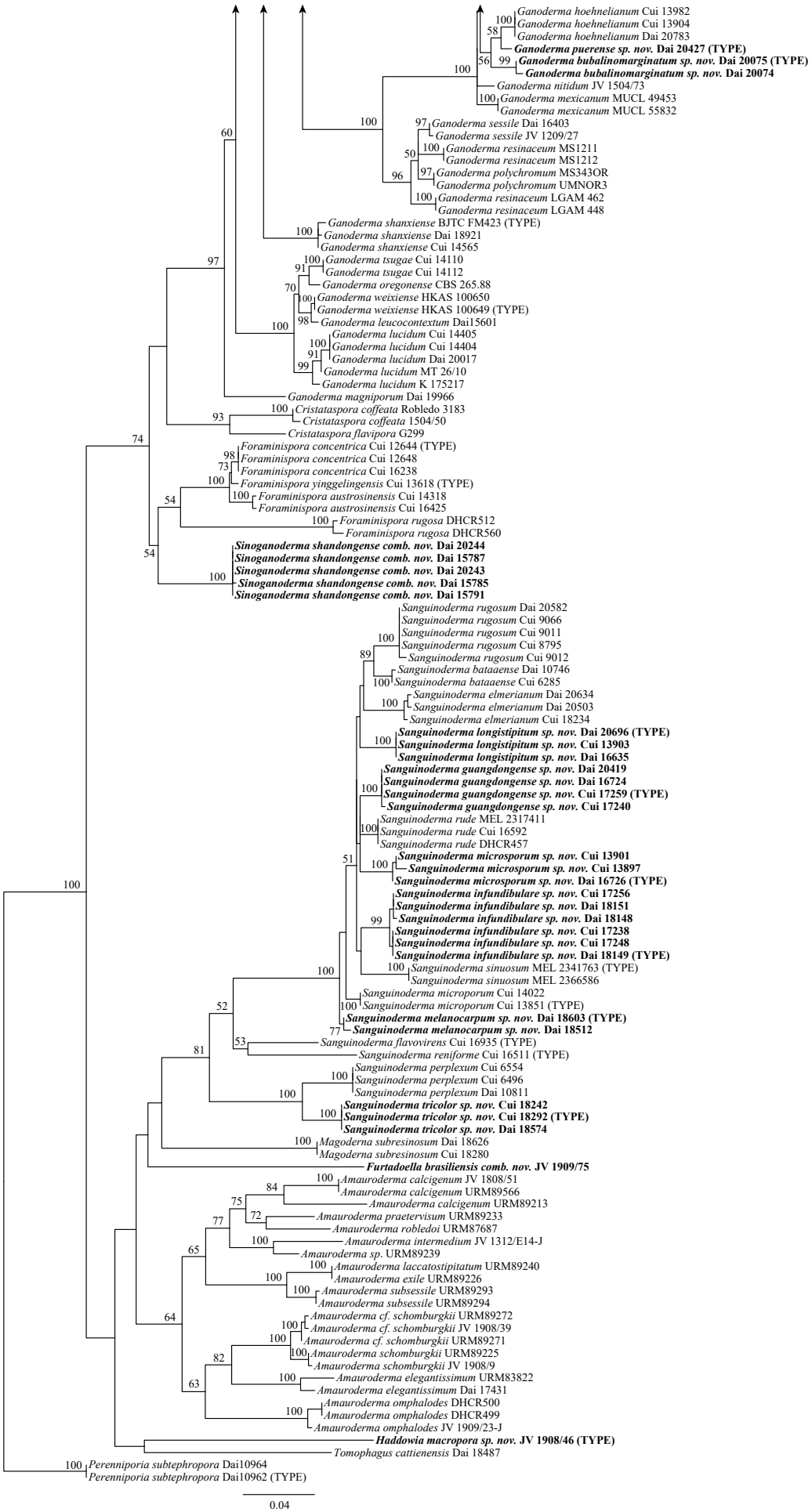

Fig. 5. (Continued).

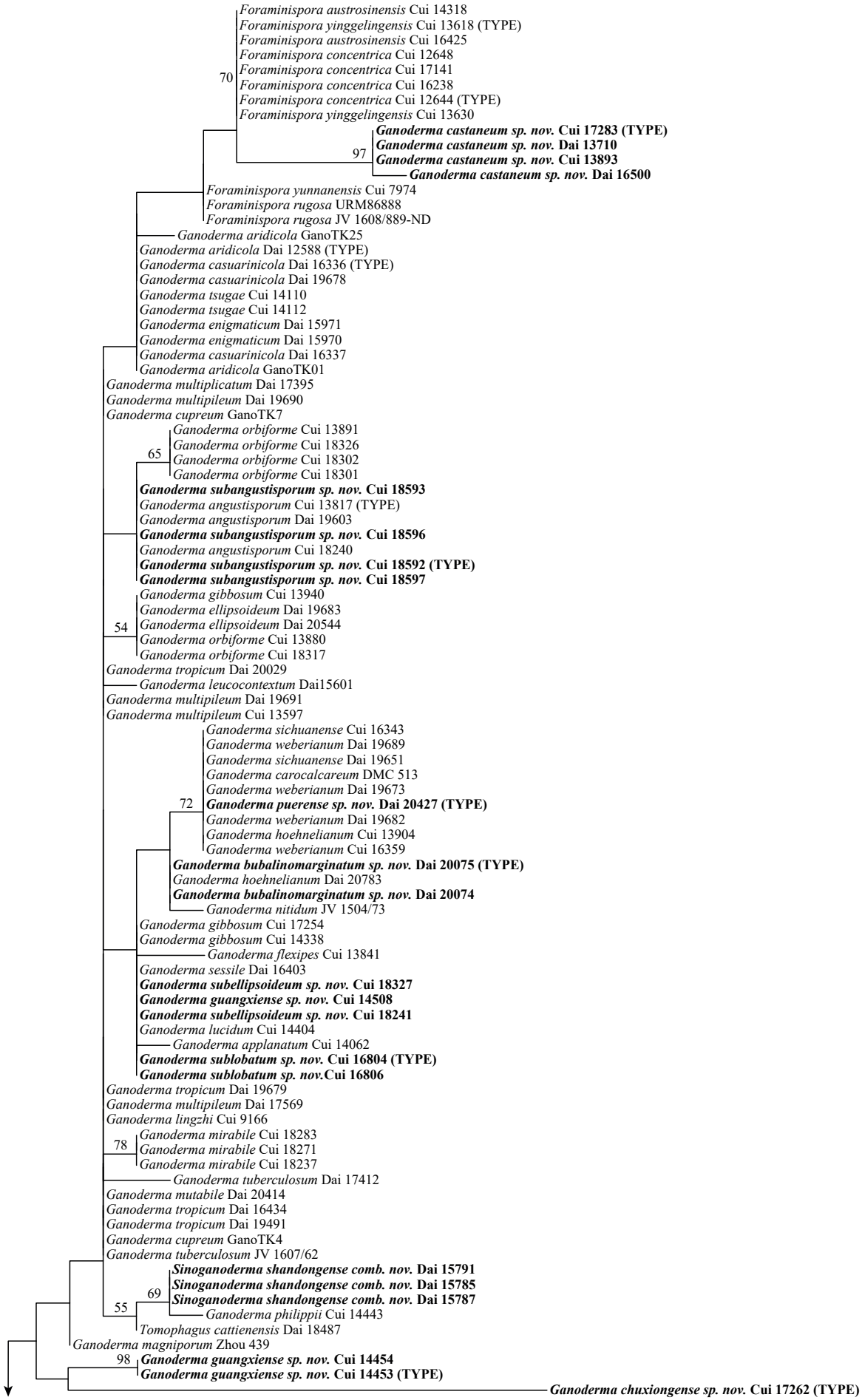

Fig. 6. Maximum Likelihood analyses of *Ganodermataceae* based on dataset of mtSSU. Maximum Likelihood bootstrap values higher than 50 % are shown. New species are in bold.

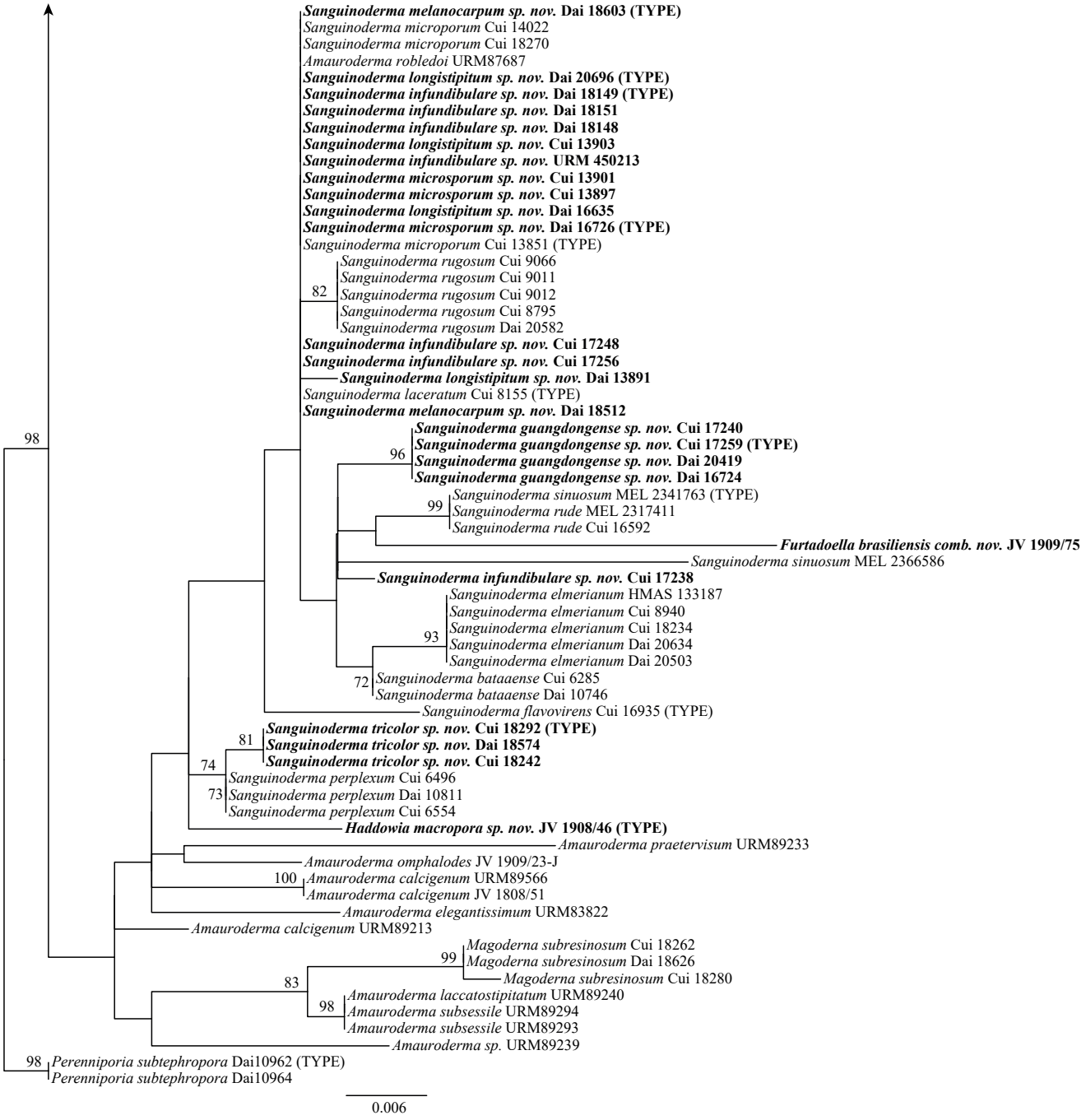

Fig. 6. (Continued).

Etymology: *furtadoella* (*Lat.*), refers to the Dr João Salvador Furtado who contributed significantly to the taxonomy of *Ganodermataceae*.

Type species: *Furtadoella biseptata* (Costa-Rezende *et al.*) B.K. Cui & Y.F. Sun.

Description: *Basidiomata* annual, stipitate, soft to corky. *Pilei* solitary, orbicular to flabelliform or infundibuliform. *Pileal surface* yellowish brown to greyish brown, dull, glabrous to tomentose, obviously concentrically zonate. *Pore surface* white to straw colour; pores circular to angular; dissepiments thin to thick, entire to lacerate. *Context* white to pale brown, with dark resinous lines, soft corky. *Hyphal system* dimitic in trama and monomitic in context; context composed of clamped to simple-septate generative hyphae, thin- to slightly thick-walled; tubes composed of clamped generative hyphae and arboriform skeletal hyphae. *Basidiospores* subglobose to ellipsoid, colourless, double-walled with verrucose to reticulate exospore wall, IKI–.

Notes: *Furtadoa* is an illegitimate name as it is a homonym of one genus in *Araceae* and was renamed as *Furtadoella* in this study. *Furtadoella* was described from the Neotropics comprising three species in Costa-Rezende *et al.* (2017). In this study one specimen collected in French Guiana supported the views of Costa-Rezende *et al.* (2017) and Sun *et al.* (2020) in the morphological and phylogenetic analyses. Under SEM, the ornamentation of basidiospores in *Furtadoella* (Fig. 8C) was obviously shown to have a verrucose to reticulate exospore wall which is similar with the ultrastructural features of *Amauroderma* and *Trachydermella*. However, *Furtadoella* can be distinguished from other genera in *Ganodermataceae* by its soft basidiomata, a monomitic hyphal structure in context and non-truncated basidiospores.

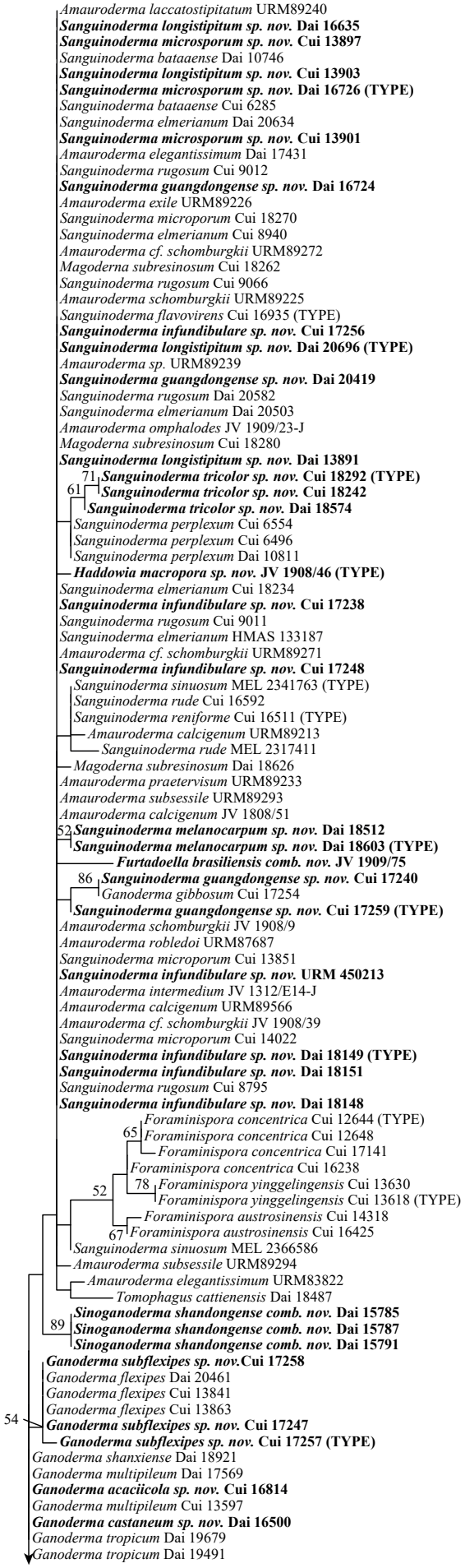

Fig. 7. Maximum Likelihood ML analyses of *Ganodermataceae* based on dataset of nSSU. Maximum Likelihood bootstrap values higher than 50 % are shown. New species are in bold.

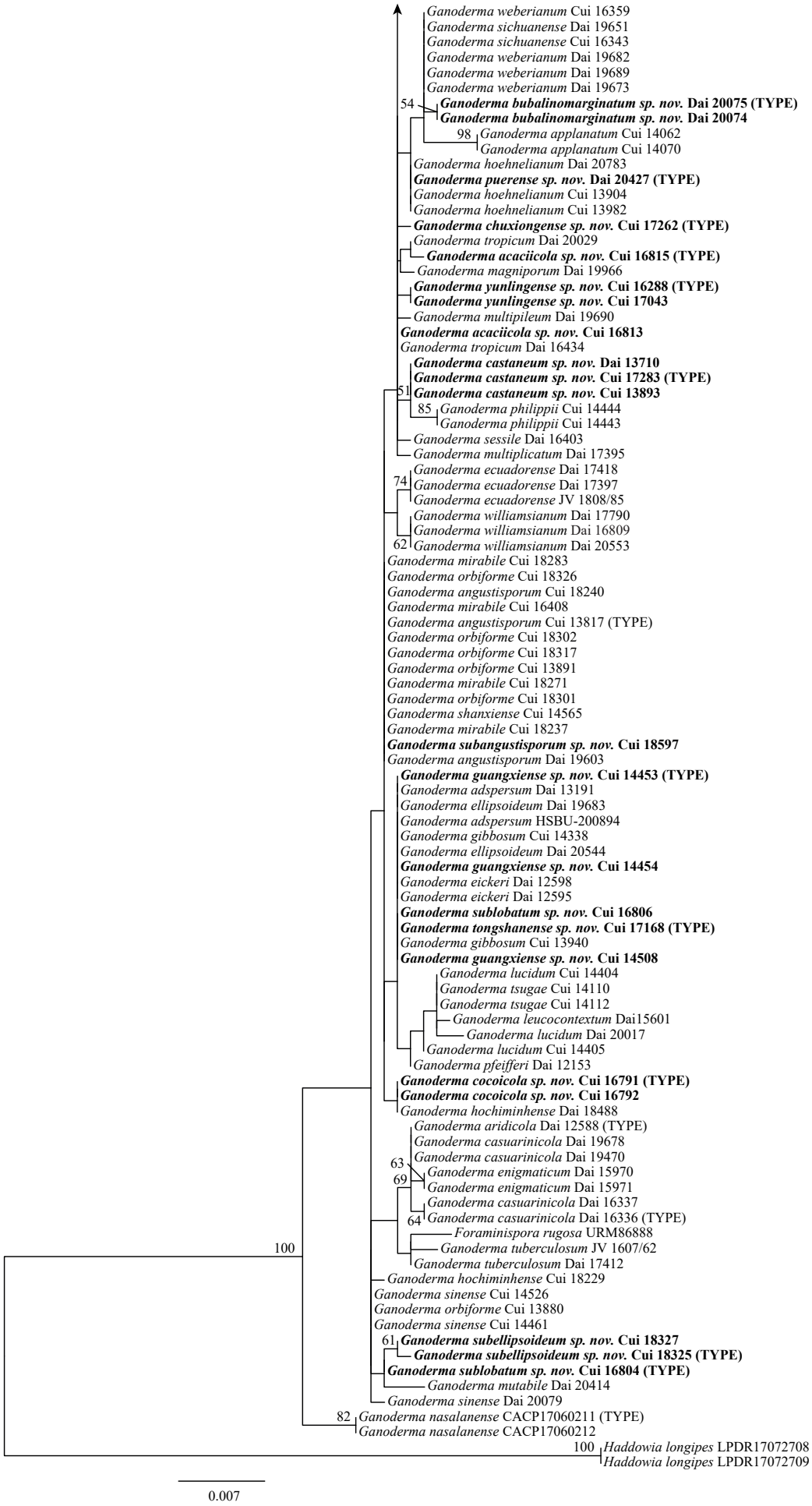

Fig. 7. (Continued).

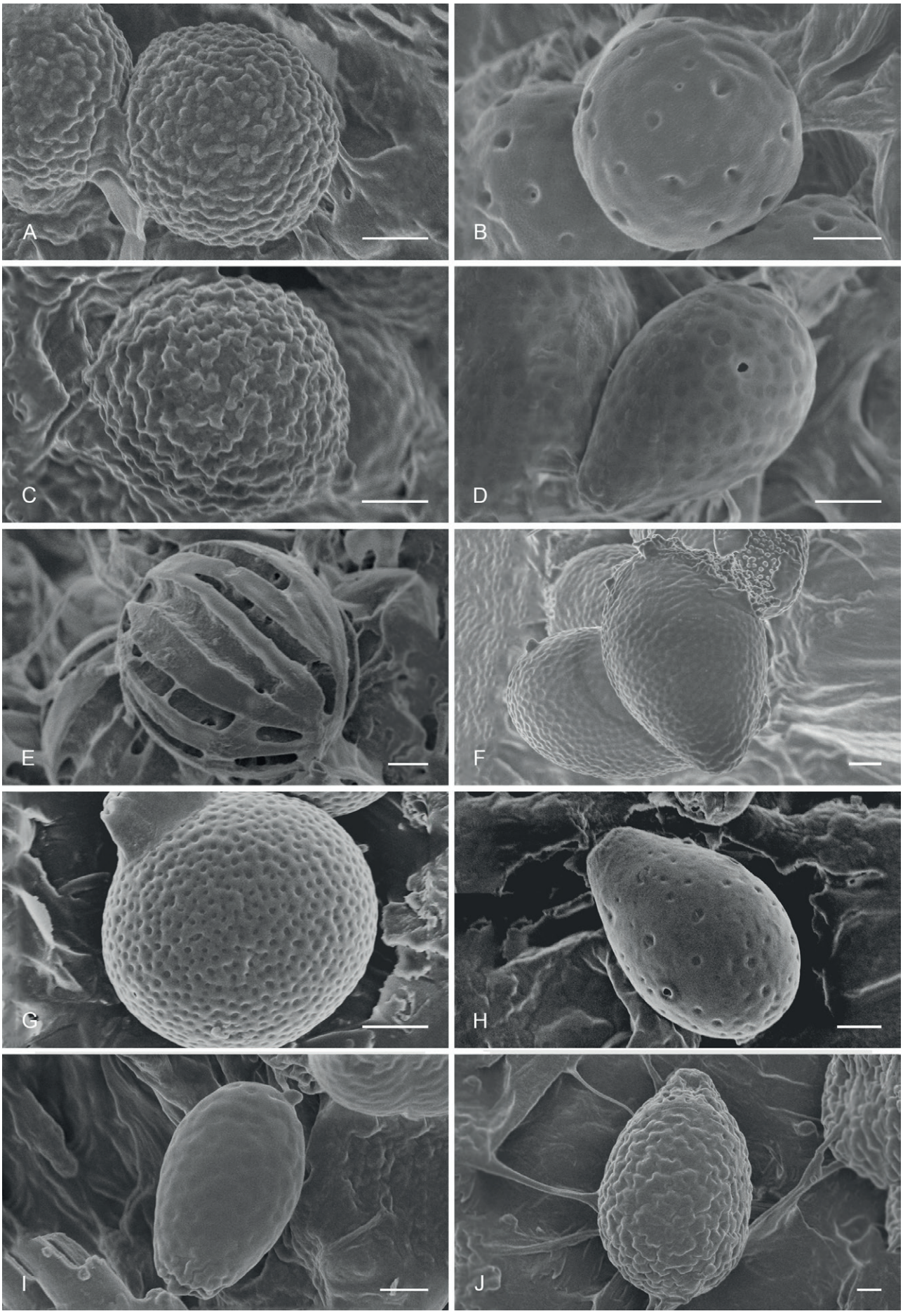

Fig. 8. Scanning Electron Micrograph (SEM) of basidiospores of 10 genera in *Ganodermataceae*. **A.** *Amauroderma schomburgkii* (JV 1908/9). **B.** *Foraminispora rugosa* (JV 1608/889-ND). **C.** *Furtadoella brasiliensis* (JV 1909/75). **D.** *Ganoderma lucidum* (Cui 14405). **E.** *Haddowia macropora* (JV 1908/46). **F.** *Magoderna subresinosum* (Cui 18280). **G.** *Sanguinoderma rude* (MEL 2150776). **H.** *Sinoganoderma shandongense* (Dai 20244). **I.** *Tomophagus cattienensis* (Dai 18487). **J.** *Trachydermella tsunodae* (Dai 3221c). Scale bars = 2 µm.

Table 2. The list of confirmed species in *Ganodermataceae*. Species in bold occur in China.

Genus	Species	Type locality	Sequences	References
Amauroderma (58)	*A. africanum*	Liberia	–	Ryvarden (2004b)
	A. albocontextum	Cameroon	–	Ryvarden (2020)
	A. albostipitatum	Brazil	–	Gomes-Silva *et al.* (2015)
	A. andinum	Venezuela	–	Ryvarden (2004b)
	A. argenteofulvum	Zimbabwe	–	Moncalvo & Ryvarden (1997)
	A. aurantiacum	Brazil	√	Gibertoni *et al.* (2008)
	A. boleticeum	Venezuela	–	Ryvarden (2004a)
	A. buloloi	Papua New Guinea	–	Moncalvo & Ryvarden (1997)
	A. calcigenum	Brazil	√	Ryvarden (2004a)
	A. calcitum	Brazil	√T	Costa-Rezende *et al.* (2016)
	A. camerarium	Brazil	√	Ryvarden (2004a)
	A. coltricioides	Guyana	–	Aime *et al.* (2003)
	A. congregatum	Malaysia	–	Corner (1983)
	A. conicum	Madagascar	–	Moncalvo & Ryvarden (1997)
	A. conjunctum	Africa	–	Moncalvo & Ryvarden (1997)
	A. deviatum	Ecuador	–	Ryvarden (2004a)
	A. ealaense	Zaire	–	Moncalvo & Ryvarden (1997)
	A. elegantissimum	Venezuela	√	Ryvarden (2004a)
	A. exile	Brazil	√	Ryvarden (2004a)
	A. faculum	Colombia	–	Henao-M (1997)
	A. flabellatum	Guyana	–	Aime *et al.* (2007)
	A. floriformum	Brazil	√T	Gomes-Silva *et al.* (2015)
	A. fuscatum	Uganda	–	Moncalvo & Ryvarden (1997)
	A. fuscoporia	Zimbabwe	–	Moncalvo & Ryvarden (1997)
	A. grandisporum	Burundi	–	Gulaid & Ryvarden (1998)
	A. insulare	Pacific: New Caledonia	–	Moncalvo & Ryvarden (1997)
	A. intermedium	Brazil	√	Ryvarden (2004a)
	A. kwiluense	Zaire	–	Ryvarden (1974)
	A. laccatostipitatum	Brazil	√	Gomes-Silva *et al.* (2015)
	A. leptopus	New Guinea	–	Furtado (1967b)
	A. leucosporum	Singapore	–	Corner (1983)
	A. malesianum	Malaysia	–	Corner (1983)
	A. minuta	Zimbabwe	–	Ryvarden (2018)
	A. nigrum	Cameroon	–	Moncalvo & Ryvarden (1997)
	A. oblongisporum	Angola	–	Campacci & Gugliotta (2009)
	A. omphalodes	Brazil	√	Ryvarden (2004a)
	A. parasiticum	Singapore	–	Corner (1983)
	A. partitum	Brazil	√	Gomes-Silva *et al.* (2010)
	A. picipes	Brazil	–	Gomes-Silva & Gibertoni (2012)
	A. praetervisum	Brazil	√	Ryvarden (2004a)
	A. preussii	Cameroon	–	Steyaert (1972)
	A. pseudoboletus	Paraguay	√	Ryvarden (2004a)
	A. pudens	India	–	Moncalvo & Ryvarden (1997)
	A. renidens	Brazil	–	Furtado (1967b), Ryvarden (2004a)
	A. robledoi	Brazil	√	Costa-Rezende *et al.* (2020a)
	A. ryvardenii	Zambia	–	Ryvarden (2020)
	A. salisburiense	Zimbabwe	–	Moncalvo & Ryvarden (1997)

Table 2. (Continued).

Genus	Species	Type locality	Sequences	References
	A. schomburgkii	Guyana	√	Ryvarden (2004a)
	A. secedens	Malaysia: Pahang	–	Corner (1983)
	A. sericatum	Nigeria	–	Moncalvo & Ryvarden (1997)
	A. sessile	Brazil	–	Gomes-Silva *et al.* (2015)
	A. solomonense	Solomon Islands	–	Corner (1983)
	A. subrugosum	Samoa Islands	–	Moncalvo & Ryvarden (1997)
	A. subsessile	Brazil	√	Gomes-Silva *et al.* (2015)
	A. tapetellum	Colombia	–	Henao-M (1997)
	A. trichodermatum	Brazil	–	Robledo *et al.* (2015)
	A. unilaterum	Brazil	–	Ryvarden (2004a)
	A. velutina	Cameroon	–	Ryvarden (2020)
Amaurodermellus (1)	*Amaurodermellus ovisporum*	Brazil	√	Gomes-Silva *et al.* (2015), Costa-Rezende *et al.* (2020b)
Cristataspora (2)	*C. coffeata*	St. Vincent	√	Costa-Rezende *et al.* (2020b)
	C. flavipora	Jamaica	√	Costa-Rezende *et al.* (2020b)
Foraminispora (5)	***Fo. austrosinensis***	China: Hainan	√	Zhao *et al.* (1984), Sun *et al.* (2020)
	Fo. concentrica	China: Sichuan	√T	Song *et al.* (2016), Sun *et al.* (2020)
	Fo. rugosa	Brazil	√	Costa-Rezende *et al.* (2017)
	Fo. yinggelingensis	China: Hainan	√T	Sun *et al.* (2020)
	Fo. yunnanensis	China: Yunnan	√	Zhao & Zhang (1986b), Sun *et al.* (2020)
Furtadoella (3)	*Fu. biseptata comb. nov.*	Brazil	√T	Costa-Rezende *et al.* (2017)
	Fu. brasiliensis comb. nov.	Brazil	√	Costa-Rezende *et al.* (2017)
	Fu. corneri comb. nov.	Brazil	–	Costa-Rezende *et al.* (2017)
Ganoderma (181)	*G. acaciicola sp. nov.*	Australia	√T	This study
	G. acontextum sp. nov.	Guatemala	√T	This study
	G. adspersum	Slovenia: Vinkovce	√	Steyaert (1972), this study
	G. aetii	Indonesia: Kalimantan	–	Zmitrovich (2018)
	G. ahmadii	Pakistan: Sialkot	–	Steyaert (1972)
	G. alluaudii	Kenya: Nairobi	–	Ryvarden (1983)
	G. alpinum sp. nov.	China: Yunnan	√T	This study
	G. amazonense	Brazil: Para State	–	Furtado (1967a)
	G. angustisporum	China: Fujian	√T	Xing *et al.* (2018)
	G. applanatum	Europe	√	Patouillard (1887)
	G. aridicola	South Africa: Durban	√T	Xing *et al.* (2016)
	G. aureolum	Angola: Tchivinguiro	–	Moncalvo & Ryvarden (1997)
	G. australe	Pacific island	√	Ryvarden (2004a)
	G. austroafricanum	South Africa: Gauteng	√	Crous *et al.* (2014)
	G. barretoi	Brazil: Madeira	–	Moncalvo & Ryvarden (1997)
	G. baudonii	Central African Republic	–	Moncalvo & Ryvarden (1997)
	G. bilobum	–	–	–
	G. boninense	Japan: Bonin Islands	√	Ryvarden (1983)
	G. brownii	USA: California	√	Steyaert (1972)
	G. bruggemanii	Indonesia: Java	–	Steyaert (1972)
	G. bubalinomarginatum sp. nov.	China: Guangxi	√T	This study
	G. calidophilum	China: Hainan	√	Cao (2013), this study
	G. capense	South Africa	–	Teng (1963)
	G. carnosum	France: Pyrenees	√	Moncalvo & Ryvarden (1997)

Table 2. (Continued).

Genus	Species	Type locality	Sequences	References
	G. carocalcareum	Cameroon	√T	Douanla-Meli & Langer (2009)
	G. castaneum sp. nov.	China: Hainan	√T	This study
	G. casuarinicola	China: Guangdong	√T	Xing *et al.* (2018)
	G. cervinum	Papua New Guinea	–	Moncalvo & Ryvarden (1997)
	G. chalceum	Sierra Leone: Kenema	√	Steyaert (1967)
	G. chocoense	Ecuador: Esmeraldas	√T	Crous *et al.* (2018)
	G. chonoides	Zaire: Shaba	–	Moncalvo & Ryvarden (1997)
	G. chuxiongense sp. nov.	China: Yunnan	√T	This study
	G. cinnamomea	Cameroon	–	Ryvarden (2020)
	G. citriporum	Venezuela: Yutaje	–	Ryvarden (2004a)
	G. cocoicola sp. nov.	Australia	√T	This study
	G. concinnum	Colombia: Choco State	√	Ryvarden (2000)
	G. corrugatum	Zaire: Kasai	–	Steyaert (1961)
	G. cupreum	Guinea	√	Moncalvo & Ryvarden (1997), this study
	G. curranii	Philippines: Luzon	–	Murrill (1908a)
	G. curtisii	USA: South Carolina	√	Murrill (1908b)
	G. dejongii	Indonesia: Java	–	Steyaert (1972)
	G. destructans	South Africa: Gauteng	√T	Coetzee *et al.* (2015)
	G. dianzhongense	China: Yunnan	√T	He *et al.* (2021)
	G. dimidiatum	Japan	–	Papp (2016)
	G. donkii	Indonesia: West Java	–	Steyaert (1972)
	G. dorsale	Brazil	–	Moncalvo & Ryvarden (1997)
	G. dubio-cochlear	Madagascar	–	Moncalvo & Ryvarden (1997)
	G. dunense	South Africa: Western Cape	√T	Tchotet Tchoumi *et al.* (2018)
	G. dussii	Guadeloupe	–	Moncalvo & Ryvarden (1997)
	G. ecuadorense	Ecuador: Orellana	√T	Crous *et al.* (2016)
	G. eickeri	South Africa	√T	Tchotet Tchoumi *et al.* (2019)
	G. elegantum	Ecuador: Yasuni National Park	–	Ryvarden (2004a)
	G. ellipsoideum	China: Hainan	√T	Hapuarachchi *et al.* (2018b)
	G. endochrum	Uganda: Entebbe	–	Moncalvo & Ryvarden (1997)
	G. enigmaticum	South Africa: Gauteng	√T	Coetzee *et al.* (2015)
	G. esculentum	China: Yunnan	√T	He *et al.* (2021)
	G. fallax sp. nov.	USA	√T	This study
	G. fassii	Congo: Ubangi	–	Steyaert (1961)
	G. fassioides	Congo: Yangambi	–	Steyaert (1961)
	G. fici	Tunisia: Gafsa	–	Moncalvo & Ryvarden (1997)
	G. flexipes	Vietnam: Tonkin	√	Steyaert (1972)
	G. fuscum	Zaire: Shaba	–	Moncalvo & Ryvarden (1997)
	G. gabonensis	Gabon	–	Decock & Ryvarden (2020)
	G. ghesquierei	Zaire: Lukoleka	–	Moncalvo & Ryvarden (1997)
	G. gibbosum	Indonesia: Java	√	Moncalvo & Ryvarden (1997), this study
	G. gilletii	Zaire: Moanda	–	Moncalvo & Ryvarden (1997)
	G. guangxiense sp. nov.	China: Guangxi	√T	This study
	G. guianensis	French Guiana	–	Ryvarden (2004a)
	G. hildebrandii	Comores Islands	–	Moncalvo & Ryvarden (1997)
	G. hinnuleum	Zaire: Yangambi	–	Moncalvo & Ryvarden (1997)

Table 2. (Continued).

Genus	Species	Type locality	Sequences	References
	G. hochiminhense	Vietnam	√T	Luangharn *et al.* (2021)
	G. hoehnelianum	Indonesia: Java	√	Luangharn *et al.* (2021)
	G. hoploides	Congo: Virunga National Park	–	Steyaert (1961)
	G. impolitum	Malaysia: Pahang	–	Moncalvo & Ryvarden (1997)
	G. insulare	Seychelles	–	Ryvarden (2020)
	G. knysnamense	South Africa	√T	Tchotet Tchoumi *et al.* (2019)
	G. kosteri	The Netherlands: Gouda	–	Steyaert (1972)
	G. lamaoense	Philippines: Lamao	–	Steyaert (1972)
	G. leucocontextum	China: Tibet	√T	Li *et al.* (2015)
	G. leucocreas	Zaire: Loango	–	Moncalvo & Ryvarden (1997)
	G. leytense	Philippines: Leyte	–	Steyaert (1972)
	G. lingua	Indonesia: Java	–	Moncalvo & Ryvarden (1997)
	G. lingzhi	China: Hubei	√T	Cao *et al.* (2012)
	G. lobatoideum	Guyana	–	Steyaert (1980)
	G. lobatum	USA: North Carolina	√	Steyaert (1980)
	G. lobenense	Cameroon	–	Kinge & Mih (2014)
	G. longistipitatum	Venezuela	–	Ryvarden (2000)
	G. lucidum	England: London	√	Steyaert (1972)
	G. luteicinctum	Singapore	–	Foroutan & Vaidya (2007)
	G. magniporum	China: Guangxi	√	This study
	G. mangiferae	Tahiti	–	Moncalvo & Ryvarden (1997)
	G. manoutchehrii	Iran: Ramsar	–	Steyaert (1972)
	G. martinicense	Martinique	√T	Welti & Courtecuisse (2010)
	G. mbrekobenum	Ghana	√T	Crous *et al.* (2016)
	G. megalosporum	Kenya: Nairobi	–	Moncalvo & Ryvarden (1997)
	G. melanophaeum	Zaire: Shaba	–	Moncalvo & Ryvarden (1997)
	G. mexicanum	Mexico	√	Torres-Torres & Guzmán-Dávalos (2012)
	G. miniatocinctum	Malaysia: Banting	–	Steyaert (1967)
	G. mirabile	Malaysia: Pahang	√	Steyaert (1972)
	G. mizoramense	India: Mizoram	√T	Crous *et al.* (2017a)
	G. multicornum	Venezuela	–	Ryvarden (2000)
	G. multipileum	China: Taiwan	√	Wang *et al.* (2009)
	G. multiplicatum	French Guiana	√	Steyaert (1980), Ryvarden (2000)
	G. mutabile	China: Yunnan	√T	Cao & Yuan (2012)
	G. myanmarense	Myanmar	√T	Luangharn *et al.* (2021)
	G. namutambalaense	Uganda	–	Moncalvo & Ryvarden (1997)
	G. nasalaense	Laos	√T	Hapuarachchi *et al.* (2019b)
	G. neogibbosum	Martinica insula	–	Welti & Courtecuisse (2010)
	G. neojaponicum	Japan: Tokyo	√T	This study
	G. nitidum	Honduras: Puerto Sierra	√	Moncalvo & Ryvarden (1997), this study
	G. ochrolaccatum	Philippines: Manila	–	Moncalvo & Ryvarden (1997)
	G. oerstedii	USA: Puerto Rico	√	Moncalvo & Ryvarden (1997)
	G. orbiforme	Guinea	√	Ryvarden (2000)
	G. oregonense	USA: Oregon	√	Murrill (1908b)
	G. ostracodes	Vietnam: Tonkin	–	Moncalvo & Ryvarden (1997)
	G. parvigibbosum	Martinique	–	Welti & Courtecuisse (2010)

Table 2. (Continued).

Genus	Species	Type locality	Sequences	References
	G. parvulum	Nicaragua	√	Ryvarden (2004a), this study
	G. petchii	Sri Lanka: Hakgala	–	Steyaert (1972)
	G. pfeifferi	Germany	√	Foroutan & Vaidya (2007)
	G. philippii	Myanmar: Mergui	√	Steyaert (1972)
	G. piceum	Malaysia	–	Ryvarden (2015)
	G. platense	Argentina	√	Moncalvo & Ryvarden (1997), this study
	G. podocarpense	Ecuador	√T	Crous *et al.* (2017b)
	G. polychromum	USA: California	√	Moncalvo & Ryvarden (1997), this study
	G. puerense sp. nov.	China: Yunnan	√T	This study
	G. puglisii	Italy: Potenza	–	Steyaert (1972)
	G. pulchella	–	–	Bresadola (1912)
	G. pygmoideum	Brazil	–	Moncalvo & Ryvarden (1997)
	G. ramosissimum	China: Yunnan	√	Zhao (1989a), this study
	G. ravenelii	USA: South Carolina	√	Steyaert (1980)
	G. resinaceum	France: Blois	√	Ryvarden (2000), Ryvarden (2004a)
	G. reticulatosporum	Zimbabwe: Harare	–	Moncalvo & Ryvarden (1997)
	G. rhacodes	–	–	Patouillard (1914)
	G. rothwellii	Zimbabwe	–	Steyaert (1980)
	G. rufoalbum	Venezuela	–	Moncalvo & Ryvarden (1997)
	G. ryvardenii	Cameroon	√T	Kinge & Mih (2011)
	G. sanduense	China: Guizhou	√T	Hapuarachchi *et al.* (2019b)
	G. sarasinii	New Caledonia: Yate	–	Steyaert (1961)
	G. sculpturatum	Madagascar	–	Moncalvo & Ryvarden (1997)
	G. septatum	Zaire: Kivu	–	Moncalvo & Ryvarden (1997)
	G. sessile	USA: New York	√	Steyaert (1972), this study
	G. sessiliforme	Mexico	√	Torres-Torres & Guzmán-Dávalos (2012)
	G. shanxiense	China: Shanxi	√T	Liu *et al.* (2019)
	G. sichuanense	China: Sichuan	√T	Zhao *et al.* (1983)
	G. silveirae	Brazil: Madeire	–	Moncalvo & Ryvarden (1997)
	G. sinense	China: Hainan	√	Zhao *et al.* (1979)
	G. soyeri	Zaire: Shaba	–	Steyaert (1961)
	G. sp.	Vietnam	√	Le *et al.* (2018)
	G. steyaertianum	Indonesia: Tirtaganga	√	Smith & Sivasithamparam (2003)
	G. stipitatum	Nicaragua	√	Murrill (1908b)
	G. subangustisporum sp. nov.	China: Yunnan	√T	This study
	G. subellipsoideum sp. nov.	Malaysia	√T	This study
	G. subflexipes sp. nov.	China: Guangdong	√T	This study
	G. sublobatum sp. nov.	Australia	√T	This study
	G. sublucidum	Zaire: Eala	–	Moncalvo & Ryvarden (1997)
	G. substipitata	–	–	Bresadola (1915)
	G. subumbraculum	Japan	–	Moncalvo & Ryvarden (1997)
	G. testaceum	Brazil	–	Moncalvo & Ryvarden (1997)
	G. thailandicum	Thailand	√T	Luangharn *et al.* (2019)
	G. tongshanense sp. nov.	China: Hubei	√T	This study
	G. tornatum	Mariana Island	√	Moncalvo & Ryvarden (1997), this study
	G. torosum	Thailand: Nakhawn Strithamarat	–	Moncalvo & Ryvarden (1997)

Table 2. (Continued).

Genus	Species	Type locality	Sequences	References
	G. trengganuense	Malaysia: Trengganu	–	Foroutan & Vaidya (2007)
	G. tropicum	Indonesia: Java	√	Steyaert (1972)
	G. trulla	Indonesia: Java	–	Moncalvo & Ryvarden (1997)
	G. trulliforme	Indonesia: Java	–	Moncalvo & Ryvarden (1997)
	G. tsugae	USA: New York	√	Murrill (1902)
	G. tuberculosum	Belize	√	Murrill (1908b)
	G. turbinatum	Uganda: Kabale	–	Ipulet & Ryvarden (2005)
	G. umbrinum	Indonesia: Java	–	Moncalvo & Ryvarden (1997)
	G. valesiacum	Switzerland: Valais	–	Moncalvo & Ryvarden (1997)
	G. vanheurnii	Indonesia: Java	–	Steyaert (1972)
	G. vanmeelii	Zaire: Shaba	–	Steyaert (1961)
	G. vivianimercedianum	Mexico	–	Torres-Torres (2008)
	G. weberianum	Samoa Islands	√	Steyaert (1972)
	G. weixiense	China: Yunnan	√T	Ye *et al.* (2019)
	G. wiiroense	Ghana	√T	Crous *et al.* (2015)
	G. williamsianum	Philippines: Luzon	√	Murrill (1907)
	G. xylonoides	Zaire: Bongabo	–	Steyaert (1961)
	G. yunlingense sp. nov.	China: Yunnan	√T	This study
	G. zonatum	USA: Florida	√	Murrill (1902)
Haddowia (2)	***Ha. longipes***	French Guyana	√	Steyaert (1972)
	Ha. macropora sp. nov.	French Guyana	√T	This study
Humphreya (3)	*Hu. eminii*	Tanzania	–	Moncalvo & Ryvarden (1997)
	Hu. endertii	Indonesia	–	Steyaert (1972)
	Hu. lloydii	–	–	Steyaert (1972)
Magoderna (2)	*M. infundibuliforme*	Uganda	–	Steyaert (1972)
	M. subresinosum	Philippines: Luzon	√	Steyaert (1972)
Neoganoderma gen. nov. (1)	***N. neurosporum comb. nov.***	Panama	√	Furtado (1967a), Ryvarden (2004a)
Sanguinoderma (16)	***Sa. bataanense***	Philippines: Luzon	√	Murrill (1908a), Sun *et al.* (2020)
	Sa. elmerianum	Philippines: Luzon	√	Murrill (1907), Sun *et al.* (2020)
	Sa. flavovirens	Zambia	√T	Sun *et al.* (2020)
	Sa. guangdongense sp. nov.	China: Guangdong	√T	This study
	Sa. infundibulare sp. nov.	China: Guangdong	√T	This study
	Sa. laceratum	China: Yunnan	√T	Sun *et al.* (2020)
	Sa. longistipitum sp. nov.	China: Yunnan	√T	This study
	Sa. melanocarpum sp. nov.	Malaysia	√T	This study
	Sa. microporum	China: Hainan	√T	Sun *et al.* (2020)
	Sa. microsporum sp. nov.	Thailand	√T	This study
	Sa. perplexum	Malaysia	√	Corner (1983), Sun *et al.* (2020)
	Sa. reniforme	Zambia	√T	Sun *et al.* (2020)
	Sa. rude	Australia: Tasmania	√	Sun *et al.* (2020)
	Sa. rugosum	Indonesia: Java	√	Sun *et al.* (2020)
	Sa. sinuosum	Australia: Queensland	√T	Sun *et al.* (2020)
	Sa. tricolor sp. nov.	Malaysia	√T	This study
Sinoganoderma gen. nov. (1)	***Si. shandongense comb. nov.***	China: Shandong	√	This study

Table 2. (Continued).

Genus	Species	Type locality	Sequences	References
Tomophagus (2)	*To. cattienensis*	Vietnam	√[T]	Le *et al.* (2012)
	To. colossus	Costa Rica	√	Le *et al.* (2012)
Trachydermella (1)	***Tr. tsunodae comb. nov.***	Japan	√	Imazeki (1952)

[T] Sequences from type specimens.

Furtadoella biseptata (Costa-Rezende *et al.*) B.K. Cui & Y.F. Sun, ***comb. nov.*** MycoBank MB 843287.
Basionym: *Furtadoa biseptata* Costa-Rezende *et al.*, Persoonia 39: 265. 2017.

Notes: *Furtadoa biseptata* was described as a new species by its simple septate generative hyphae in the context. However, due to the illegality of *Furtadoa*, this species was transferred to *Furtadoella* as a new combination in this study. The description of *Fu. biseptata* can be found in Costa-Rezende *et al.* (2017).

Furtadoella brasiliensis (Singer) B.K. Cui & Y.F. Sun, ***comb. nov.*** MycoBank MB 843289.
Basionym: *Scutiger brasiliensis* Singer, Beih. Nova Hedwigia 77: 22. 1983.

Notes: Costa-Rezende *et al.* (2017) transferred *Scutiger brasiliensis* to *Furtadoa* based on its similar morphological characters. But the name *Furatadoa* is illegitimate, and therefore *S. brasiliensis* is placed in *Furtadoella*. The description of *Fu. brasiliensis* can be found in Coelho *et al.* (2007).

Furtadoella corneri (Gulaid & Ryvarden) B.K. Cui & Y.F. Sun, ***comb. nov.*** MycoBank MB 843290.
Basionym: *Amauroderma corneri* Gulaid & Ryvarden, Mycol. Helv. 10: 28. 1998.

Notes: This species was firstly described from Brazil, and it was recombined to *Furtadoa* by its monomitic hyphal system in context (Costa-Rezende *et al.* 2017). In this study, *Amauroderma corneri* was treated as a new combination in *Furtadoella* due to the illegality of *Furtadoa*. The detailed description of *Fu. corneri* can be found in Gulaid & Ryvarden (1998).

Ganoderma P. Karst., Revue Mycol., Toulouse 3: 17. 1881. MycoBank MB 17639.

Type species: *Ganoderma lucidum* (Curtis) P. Karst.

Description: *Basidiomata* annual to perennial, sessile or subsessile to stipitate. *Pilei* solitary or imbricate, of variable shape. *Pileal surface* pale brown, reddish brown to almost black, dull to laccate, with variable ornamentation. *Context* homogeneous or heterogeneous. *Tubes* stratified or not. *Hyphal system* trimitic,

Fig. 9. Basidiomata of *Ganoderma acaciicola*.

generative hyphae usually with clamp connections. *Basidiospores* subglobose to ellipsoid or ovoid, truncated, double-walled with thick walls, exospore wall semi-reticulate, endospore wall smooth or with conspicuous spinules.

Notes: In this study, 95 species of *Ganoderma* were included to construct the phylogenetic tree, and they formed an independent clade with proper support (Fig. 1). Based on morphological characters and phylogenetic evidence, 16 new species are described and illustrated. In addition, 28 known species are also described, and a key to confirmed species of *Ganoderma* in China is provided.

Ganoderma acaciicola B.K. Cui, J.H. Xing & Y.F. Sun, ***sp. nov.*** MycoBank MB 839670. Figs 9, 10.

Diagnosis: Differs from other species in the genus by its sessile and concrescent basidiomata with reddish brown and laccate pileal surface, homogeneous context, non-stratified tubes, cream to buff pore surface unchanging when bruised, broadly ellipsoid to ovoid basidiospores with truncated apex.

Etymology: *acaciicola* (*Lat.*), refers to this species growing on *Acacia*.

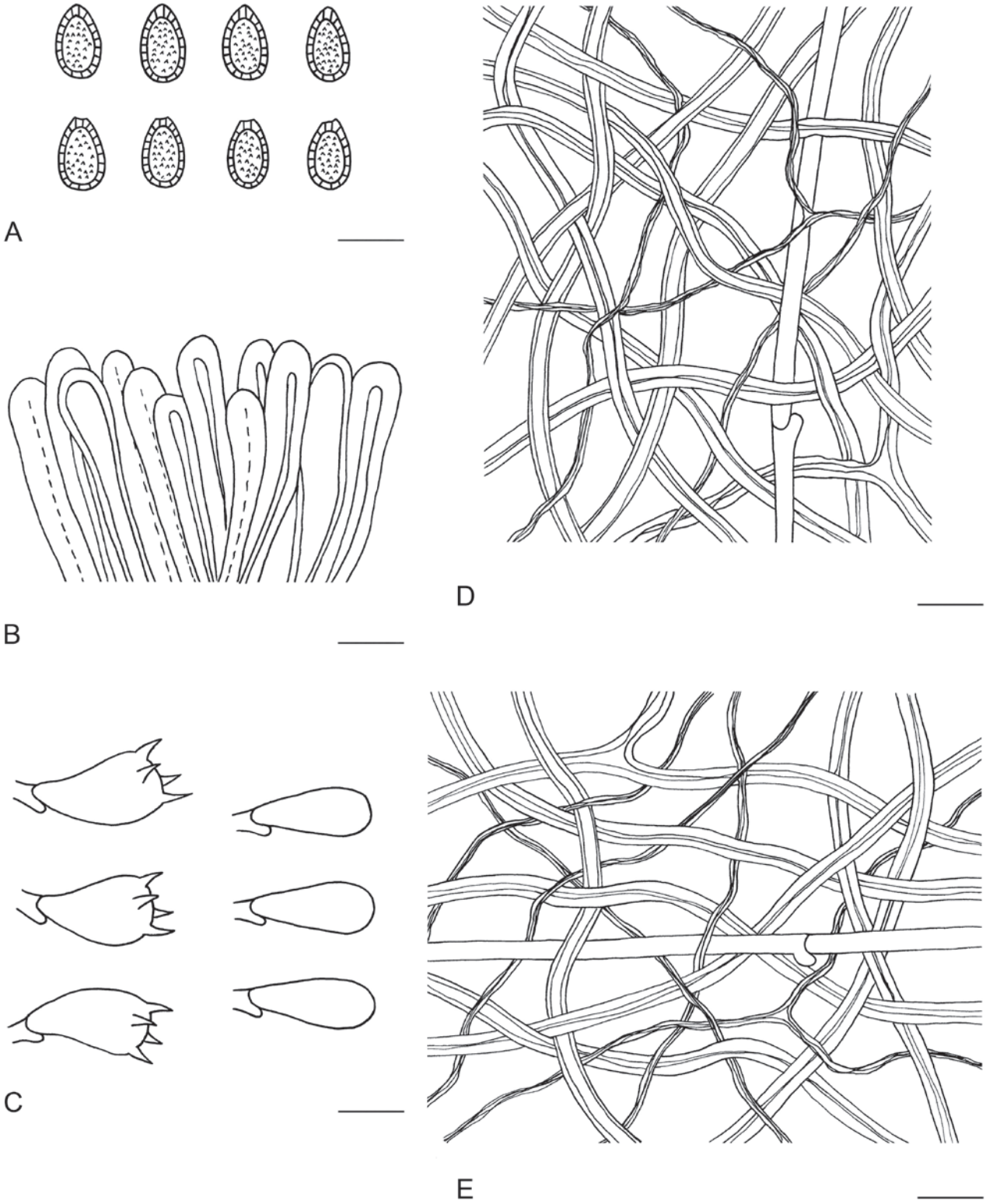

Fig. 10. Microscopic structures of *Ganoderma acaciicola* (drawn from Cui 16815). **A.** Basidiospores. **B.** Apical cells from cuticle. **C.** Basidia and basidioles. **D.** Hyphae from trama. **E.** Hyphae from context. Scale bars = 10 µm.

Typus: **Australia**, Queensland, Cairns, on stump of *Acacia*, 18 May 2018, Cui 16815 (**holotype** BJFC030114).

Additional materials examined: **Australia**, Queensland, Cairns, on stump of *Acacia*, 18 May 2018, Cui 16813 (BJFC030112), Cui 16814 (BJFC030113); on root of living *Acacia*, 18 May 2018, Cui 16817 (BJFC030116).

Description: *Basidiomata* annual, sessile or subsessile and broadly attached, usually concrescent, hard corky to woody hard. *Pilei* subcircular to flabelliform, up to 16.5 cm diam and 3 cm thick. *Pileal surface* rusty orange brown to reddish brown, laccate, glabrous, pileal margin distinct, cream buff; margin obtuse, entire, irregularly wavy. *Pore surface* cream to buff when fresh, unchanging when bruised, pale straw yellow when dry; pores circular to angular, 4–6 per mm; dissepiments moderately thick, entire. *Context* cinnamon brown to dark brown, homogeneous, with black melanoid lines, hard corky, up to 2 cm thick. *Tubes* yellowish brown to greyish brown, non-stratified, up to 1 cm long. *Hyphal system* trimitic; generative hyphae with clamp connections; all hyphae IKI –, CB +; tissues darkening in KOH. Generative hyphae in context colourless, thin-walled, 2–4 µm diam; skeletal hyphae in context dark brown, thick-walled with a wide to narrow lumen or sub-solid, arboriform and flexuous, 2–6 µm diam; binding hyphae in context colourless, thick-walled, branched and flexuous, up to 1 µm diam. Generative hyphae in tubes colourless, thin-walled, 2–3 µm diam; skeletal hyphae in tubes pale yellowish brown, thick-walled with a wide to narrow lumen or sub-solid, arboriform and flexuous, 2–4 µm diam; binding hyphae in tubes colourless, thick-walled, branched and flexuous, up to 1 µm diam. *Pileipellis* composed of clamped generative hyphae, thick-walled to sub-solid, apical cells clavate, inflated and flexuous, pale yellow to golden yellow, about 25–38 × 6–10 µm, forming a regular palisade. *Cystidia* and *cystidioles* absent. *Basidia* barrel-shaped, colourless, thin-walled, 15–20 × 9–12 µm; *basidioles* clavate, colourless, thin-walled, 15–20 × 6–10 µm. *Basidiospores* broadly ellipsoid to ovoid, truncated, yellowish brown, IKI –, CB +, double-walled with distinctly thick walls, exospore wall smooth, endospore wall with dense spinules, (9–)9.2–11.3(–11.6) × (5–)5.6–7 µm, L = 10.12 µm, W = 6.29 µm, Q = 1.61 (n = 60/2, with the turgid vesicular appendix excluded); (10.5–)10.7–11.8(–12.1) × (5.5–)5.8–7 µm, L = 11.12 µm, W = 6.31 µm, Q = 1.72–1.81 (n = 60/2, with the turgid vesicular appendix included).

Notes: *Ganoderma acaciicola* was collected from Australia on *Acacia*. It can be characterised by concrescent basidiomata without a stipe, rusty orange brown to reddish brown and laccate pileal surface, pore surface unchanging when bruised. In the phylogenetic analyses, *G. acaciicola* is closely related to *G. mizoramense* which was described from Mizoram, India; however, its stipitate basidiomata with irregular pileal surface, ellipsoid basidiospores in larger size (10–12.5 × 6–9 µm, Crous *et al.* 2017a) differentiate it from *G. acaciicola*.

Ganoderma acontextum B.K. Cui, J.H. Xing & Vlasák, ***sp. nov.*** MycoBank MB 805754. Figs 11, 12.

Diagnosis: Differs from other species in the genus by its ungulate pilei with non-laccate pileal surface, heterogeneous and thin context, non-stratified tubes, almond-shaped basidiospores without spinules on the endospore wall.

Etymology: *acontextum* (*Lat.*), refers to the basidiomata having extremely thin context.

Typus: **Guatemala**, San Mateo, on angiosperm tree, 22 Nov. 2006 (**holotype** JV 0611/21G).

Fig. 11. Basidiomata of *Ganoderma acontextum*.

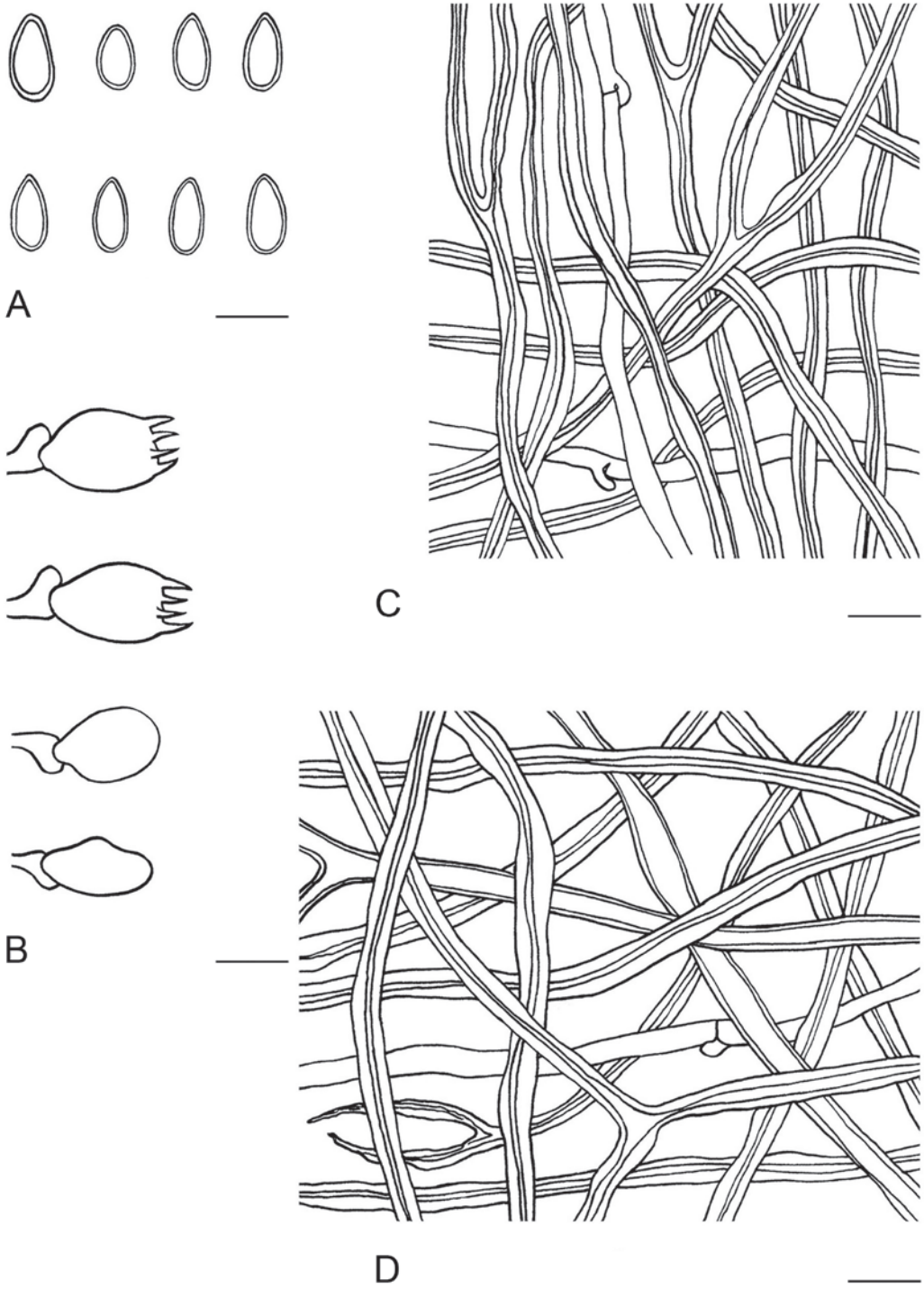

Fig. 12. Microscopic structures of *Ganoderma acontextum* (drawn from JV 0611/21G). **A.** Basidiospores. **B.** Basidia and basidioles. **C.** Hyphae from trama. **D.** Hyphae from context. Scale bars = 10 µm.

Additional materials examined: **USA**, Virginia, Woodbridge, Mason Neck State Park, on *Quercus*, 11 Aug. 2012, JV 1208/11J, JV 1407/64 (JV).

Diagnosis: *Basidiomata* perennial, sessile, woody hard. *Pilei* solitary, ungulate to columnar at maturity, up to 6 cm diam and 4 cm thick. *Pileal surface* reddish brown to dark brown, dull, glabrous, with dense concentric furrows; margin obtuse, entire, wavy. *Pore surface* white when fresh, turning darker when bruised, clay-buff to dark brown when dry; pores circular, 4–6 per mm; dissepiments thick, entire. *Context* dark brown, heterogeneous, composed of a strikingly light brown to ochre zone under pileal crust, followed by black melanoid lines, and dark brown context above the tubes, corky, thin, up to 3 mm thick altogether. *Tubes* dark brown, non-stratified, up to 4 cm long. *Hyphal system* trimitic; generative hyphae with clamp connections; skeletal hyphae occasionally with simple septa; all hyphae IKI –, CB +; tissues darkening in KOH. Generative hyphae in context colourless, thin-walled, 2–3 µm diam; skeletal hyphae in context yellow to brown, thick-walled with a wide to narrow lumen or sub-solid, arboriform and flexuous, 2–5 µm diam; binding hyphae in context colourless, thick-walled, branched and flexuous, 1.2–2.5 µm diam. Generative hyphae in tubes colourless, thin-walled, 2.2–2.8 µm diam; skeletal hyphae in tubes pale brown to brown, thick-walled with a wide to narrow lumen or sub-solid, arboriform and flexuous, 2.3–4 µm diam; binding hyphae in tubes colourless, thick-walled, branched and flexuous, 1–2.5 µm diam. *Cystidia* and *cystidioles* absent. *Basidia* broadly clavate, colourless, thin-walled, 20–30 × 7–11 µm; *basidioles* in shape like the basidia, colourless, thin-walled, 14–25 × 6–10 µm. *Basidiospores* almond-shaped, not obviously

truncated, golden-brown, IKI –, CB +, double-walled with slightly thick walls, exospore wall smooth, endospore wall without spinules, (9–)9.8–10.2(–11) × (4–)5.5–6.3(–6.5) µm, L = 9.89 µm, W = 5.73 µm, Q = 1.73 (n = 30/1, with the turgid vesicular appendix excluded).

Notes: *Ganoderma acontextum* was collected from Central America and the USA belonging to the non-laccate group. It has distinctive features such as ungulate pilei with densely concentrically furrowed pileal surface, heterogeneous and thin context, non-stratified tubes, almond-shaped basidiospores without an obviously truncated apex, and no spinules on the endospore wall.

Ganoderma alpinum B.K. Cui, J.H. Xing & Y.F. Sun, ***sp. nov.*** MycoBank MB 839671. Figs 13, 14.

Diagnosis: Differs from other species in the genus by its perennial and sessile basidiomata, pale brown to greyish brown pileal surface with concentric furrows and radial wrinkles, cracked margin, homogeneous context and non-stratified tubes.

Etymology: *alpinum* (*Lat.*), refers to this species being collected from an alpine area.

Typus: **China**, Yunnan, Shangri-La, Daxueshan, on stump of *Populus*, 12 Aug. 2019, Cui 17467 (**holotype** BJFC034326).

Additional materials examined: **China**, Sichuan, Yajiang County, on stump of *Pinus*, 8 Aug. 2019, Cui 17325 (BJFC034183); Xizang, Chayu County, on stump of *Cupressus*, 10 Sep. 2020, Cui 18402 (BJFC035263).

Description: *Basidiomata* perennial, sessile, woody hard. *Pilei* flabelliform to shell-shaped, applanate, up to 15 cm diam and 4 cm thick. *Pileal surface* pale brown to greyish brown, dull, glabrous, with concentric furrows and radial wrinkles; margin subacute to obtuse, entire, slightly wavy, cracked when dry. *Pore surface* white to cream when fresh, turning darker when bruised, clay buff to dark brown when dry; pores circular, 5–7 per mm; dissepiments slightly thick, entire. *Context* cinnamon brown to dark brown, homogeneous, with black melanoid lines, hard corky and fibrous, up to 2 cm thick. *Tubes* yellowish brown to dark brown, non-stratified, up to 2 cm long. *Hyphal system* trimitic; generative hyphae with clamp connections; all hyphae IKI –, CB +; tissues darkening in KOH. Generative hyphae in context colourless, thin-walled, 3–4 µm diam; skeletal hyphae in context pale yellowish brown, thick-walled with a wide to narrow lumen or sub-solid, arboriform and flexuous, 3–6 µm diam; binding hyphae in context colourless, thick-walled, branched and flexuous, up to 2 µm diam. Generative hyphae in tubes colourless, thin-walled, 2–4 µm diam; skeletal hyphae in tubes pale brown, thick-walled with a wide to narrow lumen or sub-solid, arboriform and flexuous, 3–5 µm diam; binding hyphae in tubes colourless, thick-walled, branched and flexuous, up to 2 µm diam. *Pileipellis* composed of clamped generative hyphae, thick-walled, apical cells clavate, slightly inflated and flexuous, yellowish brown, about 20–30 × 5–8 µm, forming a regular palisade. *Cystidia* and *cystidioles* absent. *Basidia* barrel-shaped, colourless, thin-walled, 20–30 × 11–16 µm; *basidioles* clavate, colourless, thin-walled, 12–18 × 6–10 µm. *Basidiospores* broadly ellipsoid to ovoid, truncated, yellowish brown, IKI –, CB +, double-walled with distinctly thick walls, exospore wall smooth, endospore wall with dense spinules, (6.2–)6.3–7.6(–7.8) × (4–)4.1–5.4(–5.5) µm, L = 6.97 µm, W = 4.83 µm, Q = 1.43–1.45 (n = 60/2,

Fig. 13. Basidiomata of *Ganoderma alpinum*.

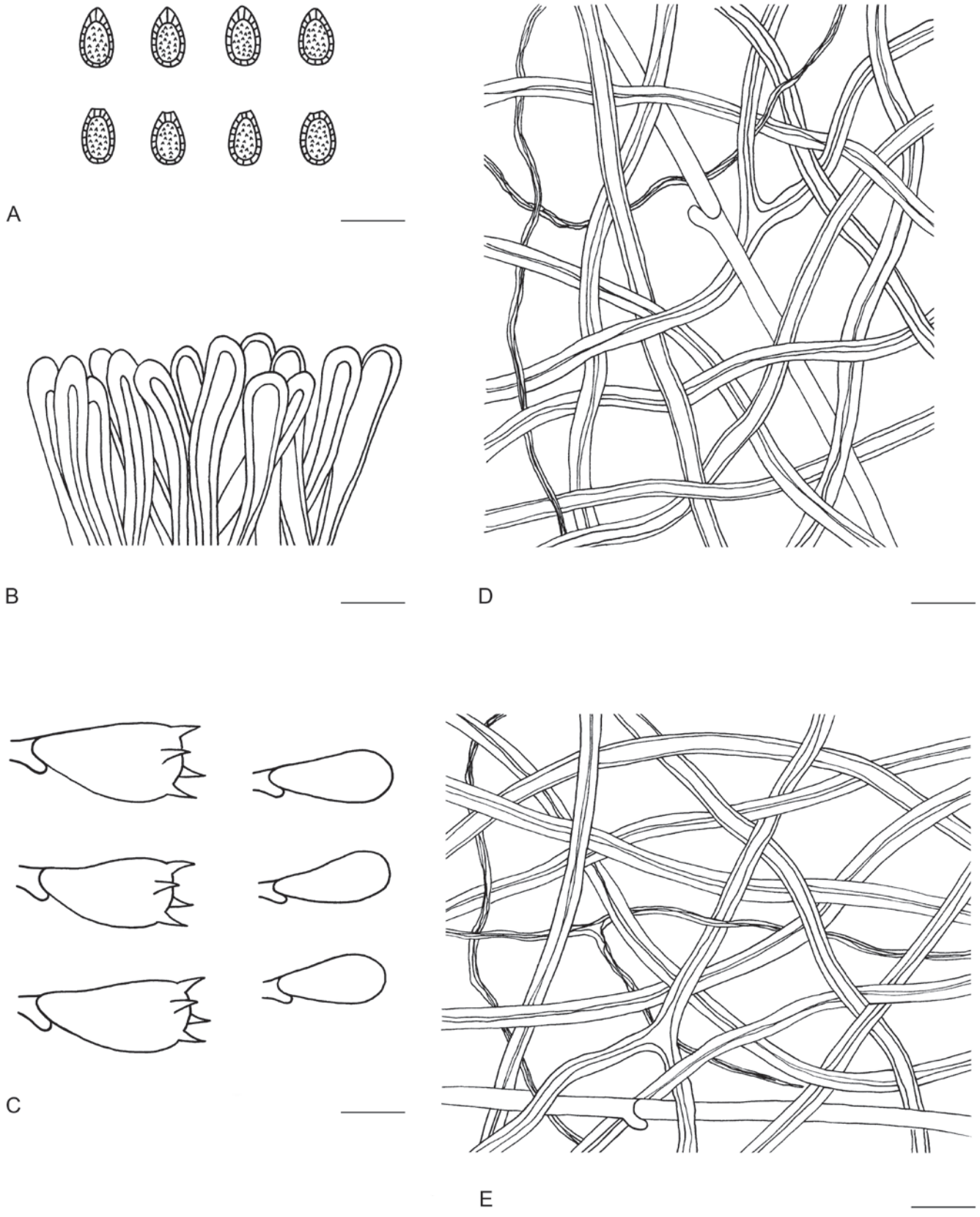

Fig. 14. Microscopic structures of *Ganoderma alpinum* (drawn from Cui 17467). **A.** Basidiospores. **B.** Apical cells from cuticle. **C.** Basidia and basidioles. **D.** Hyphae from trama. **E.** Hyphae from context. Scale bars = 10 µm.

with the turgid vesicular appendix excluded); (7.7–)7.8–9.2(–9.4) × (4–)4.1–5.4(–5.8) µm, L = 8.37 µm, W = 4.85 µm, Q = 1.71–1.74 (n = 60/2, with the turgid vesicular appendix included).

Notes: *Ganoderma alpinum* was collected from high altitude areas of southwestern China. It is hard to distinguish *G. alpinum* from *G. applanatum* on morphology, however, *G. alpinum* can be separated from *G. applanatum* by phylogenetic analyses and ecological distribution.

Ganoderma bubalinomarginatum B.K. Cui, J.H. Xing & Y.F. Sun, ***sp. nov.*** MycoBank MB 839672. Figs 15, 16.

Fig. 15. Basidiomata of *Ganoderma bubalinomarginatum*.

Diagnosis: Differs from other species in the genus by its pale-coloured basidiomata without stipe, laccate pileal surface with buff margin, homogeneous context and non-stratified tubes.

Etymology: *bubalinomarginatum* (*Lat.*), refers to the pilei with buff margin.

Typus: **China**, Guangxi, Nanning, Guangxi Academy of Forestry, on stump of *Castanopsis*, 4 Jul. 2019, Dai 20075 (**holotype** BJFC031749).

Additional material examined: **China**, Guangxi, Nanning, Guangxi Academy of Forestry, on living tree of *Phoebe*, 4 Jul. 2019, Dai 20074 (BJFC031748).

Description: *Basidiomata* annual, sessile and broadly attached, usually concrescent, hard corky. *Pilei* solitary, flabelliform to shell-shaped, up to 7.5 cm diam and 6 mm thick. *Pileal surface* reddish brown at the base, yellowish brown at the centre, buff at the margin, laccate, glabrous, with wide concentric furrows and slightly radial wrinkles; margin obtuse, entire, wavy when dry. *Pore surface* white to greyish white when fresh, turning darker when bruised, pale wood brown to greyish brown when dry; pores circular to angular, 5–6 per mm; dissepiments moderately thick, entire. *Context* straw yellow, homogeneous, without black melanoid lines, hard corky, up to 4 mm thick. *Tubes* pale brown, non-stratified, up to 3 mm long. *Hyphal system* trimitic; generative hyphae with clamp connections; all hyphae IKI –, CB +; tissues darkening in KOH. Generative hyphae in context colourless, thin-walled, 2–4 µm diam; skeletal hyphae in context pale yellow, thick-walled with a wide to narrow lumen or sub-solid, arboriform and flexuous, 2–5 µm diam; binding hyphae in context colourless, thick-walled, rarely branched and flexuous, up to 2 µm diam. Generative hyphae in tubes colourless, thin-walled, 2–3 µm diam; skeletal hyphae in tubes pale yellow, thick-walled with a wide to narrow lumen or sub-solid, arboriform and flexuous, 2–4 µm diam; binding hyphae in tubes colourless, thick-walled, rarely branched and flexuous, up to 1.5 µm diam. *Pileipellis* composed of clamped generative hyphae, thick-walled to sub-solid, apical cells clavate, inflated and flexuous, pale golden yellow, about 28–42 × 9–11 µm, forming a regular palisade. *Cystidia* and *cystidioles* absent. *Basidia* broadly clavate, colourless, thin-walled, 15–22 × 7–11 µm; *basidioles* in shape like the basidia, colourless, thin-walled, 12–20 × 5–9 µm. *Basidiospores* broadly ellipsoid to ovoid, truncated, pale yellowish brown, IKI –, CB +, with oily drop, double-walled with slightly thick walls, exospore wall smooth, endospore wall with dense spinules, (6.2–)6.5–7.4(–7.6) × (4.2–)4.5–5.3(–5.8) µm, L = 6.91 µm, W = 4.87 µm, Q = 1.41–1.43 (n = 60/2, with the turgid vesicular appendix excluded); (7–)7.2–8.3(–8.8) × (4.3–)4.5–5.6(–5.8) µm, L = 7.82 µm, W = 4.96 µm, Q = 1.57–1.59 (n = 60/2, with the turgid vesicular appendix included).

Notes: *Ganoderma bubalinomarginatum* has pale-coloured basidiomata without a stipe which differentiates it from the species described from Guangxi Autonomous Region: *G. daiqingshanense*, *G. guinanense* and *G. magniporum*. *Ganoderma*

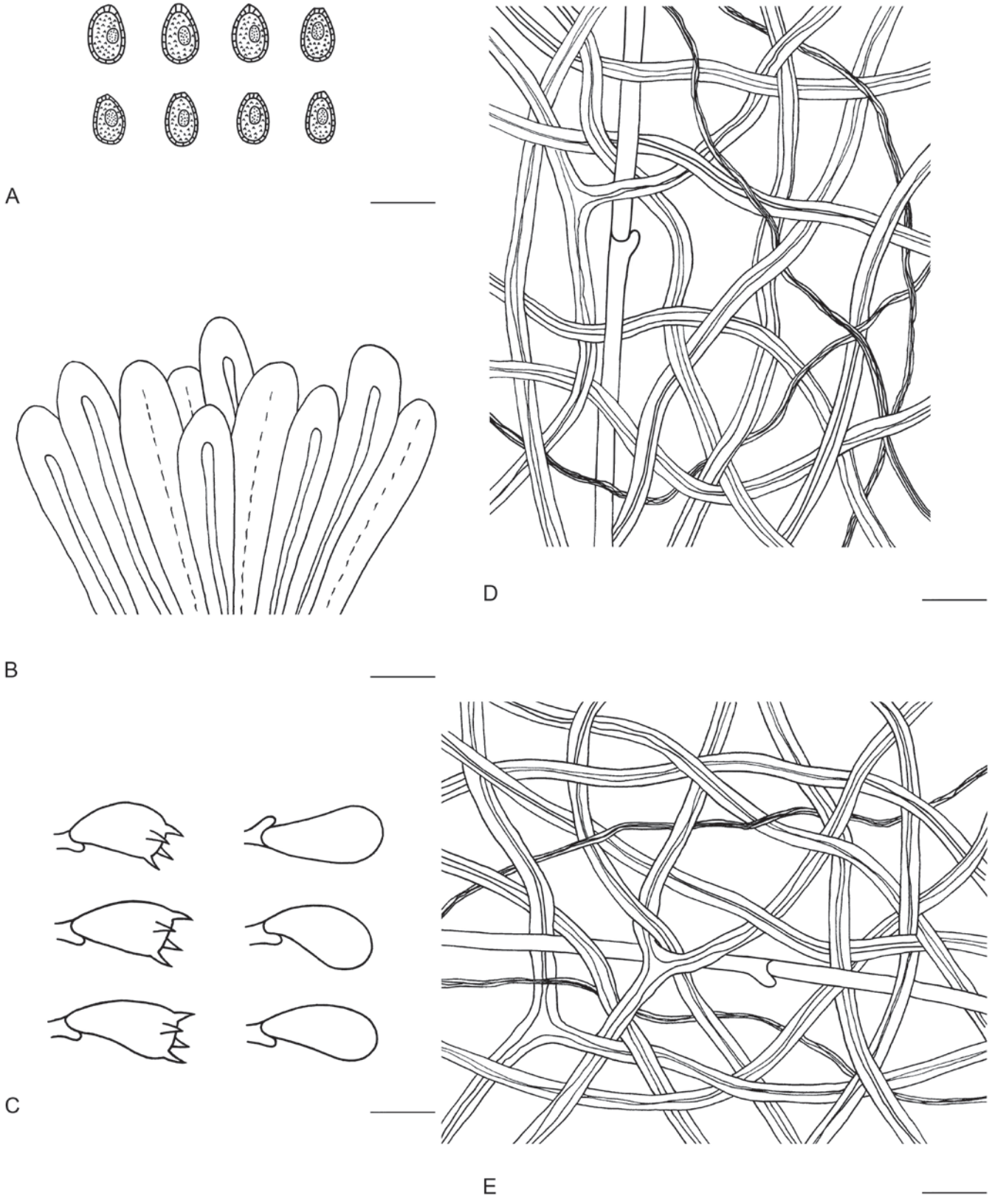

Fig. 16. Microscopic structures of *Ganoderma bubalinomarginatum* (drawn from Dai 20075). **A.** Basidiospores. **B.** Apical cells from cuticle. **C.** Basidia and basidioles. **D.** Hyphae from trama. **E.** Hyphae from context. Scale bars = 10 µm.

bubalinomarginatum is like *G. sessile*, described from America: it shares connate and sessile basidiomata, reddish brown to yellowish brown pileal surface, absence of black melanoid lines, white pore surface when fresh, homogeneous context and non-stratified tubes. However, *G. sessile* differs by the white, thin and acute pileal margin, larger pores (3–5 per mm), and larger basidiospores (9–11 × 6–8 µm, Murrill 1902).

Ganoderma castaneum B.K. Cui, J.H. Xing & Y.F. Sun, ***sp. nov.*** MycoBank MB 839673. Figs 17, 18.

Diagnosis: Differs from other species in the genus by its chestnut brown and laccate pileal surface with wide concentric ridges, heterogeneous context, and broadly ellipsoid basidiospores with smooth endospore wall.

Fig. 17. Basidiomata of *Ganoderma castaneum*.

Etymology: *castaneum* (*Lat.*), refers to the reddish brown pileal surface like a chestnut.

Typus: **China**, Hainan, Ledong County, Jianfengling Nature Reserve, on stump of angiosperm tree, 3 Jul. 2019, Cui 17283 (**holotype** BJFC034139).

Additional materials examined: **China**, Hainan, Ledong County, Jianfengling Nature Reserve, on stump of angiosperm tree, 17 Jun. 2014, Dai 13710 (BJFC017447); on fallen branch of angiosperm tree, 19 Jun. 2016, Cui 13893 (BJFC028759); Wuzhishan, Wuzhishan Forest Park, on stump of *Acacia*, 11 Jun. 2016, Dai 16500 (BJFC022616), Dai 16501 (BJFC022617).

Description: *Basidiomata* annual, sessile, broadly attached, hard corky to woody hard. *Pilei* solitary, flabelliform, applanate, up to 8.5 cm diam and 2 cm thick. *Pileal surface* reddish brown like chestnut, laccate, glabrous, with wide concentric ridges and slightly radial wrinkles; margin obtuse, entire, wavy. *Pore surface* white to cream when fresh, turning darker when bruised, buff to pale straw yellow when dry; pores circular, 4–6 per mm; dissepiments moderately thick, entire. *Context* heterogeneous, the upper layer pale straw yellow, the lower layer cinnamon brown to dark brown, with black melanoid lines, hard corky, up to 1.6 cm thick. *Tubes* pale greyish brown, non-stratified, up to 5 mm long. *Hyphal system* trimitic; generative hyphae with clamp connections; all hyphae IKI –, CB +; tissues darkening in KOH. Generative hyphae in context colourless, thin-walled, 2–4 µm diam; skeletal hyphae in context pale yellowish brown, thick-walled with a wide to narrow lumen or sub-solid, arboriform and flexuous, 3–6 µm diam; binding hyphae in context colourless, thick-walled, branched and flexuous, up to 2 µm diam. Generative hyphae in tubes colourless, thin-walled, 2–4 µm diam; skeletal hyphae in tubes pale yellowish brown, thick-walled with a wide to narrow lumen or sub-solid, arboriform and flexuous, 2–6 µm diam; binding hyphae in tubes colourless, thick-walled, branched and flexuous, up to 1 µm diam. *Pileipellis* composed of clamped generative hyphae, slightly thick-walled, apical cells clavate, flexuous, pale yellow, about 25–40 × 3–5 µm, forming a regular palisade. *Cystidia* and *cystidioles* absent. *Basidia* barrel-shaped, colourless, thin-walled, 14–21 × 7–12 µm; *basidioles* broadly clavate, colourless, thin-walled, 9–12 × 5–10 µm. *Basidiospores* broadly ellipsoid, not obviously truncated, golden yellow, IKI –, slightly CB +, double-walled with distinctly thick walls, exospore and endospore walls smooth, (6.2–)6.7–8.3(–8.5) × (4.2–)4.8–6(–6.3) µm, L = 7.42 µm, W = 5.43 µm, Q = 1.37 (n = 60/1, with the turgid vesicular appendix excluded).

Notes: *Ganoderma castaneum* was collected from a tropical rainforest of Hainan Province. When compared with the species in the checklist of *Ganoderma* reported from Hainan Island by Hapuarachchi *et al.* (2018b), *G. castaneum* has distinguished features such as chestnut-coloured and laccate pileal surface with wide concentric ridges, heterogeneous context, broadly ellipsoid and basidiospores not obviously truncated with smooth endospore walls.

Ganoderma chuxiongense B.K. Cui, J.H. Xing & Y.F. Sun, ***sp. nov.*** MycoBank MB 840397. Figs 19, 20.

Diagnosis: Differs from other species in the genus by its thin basidiomata, dimidiate and lobate pileus with reddish brown and laccate pileal surface, pale light-yellow pore surface.

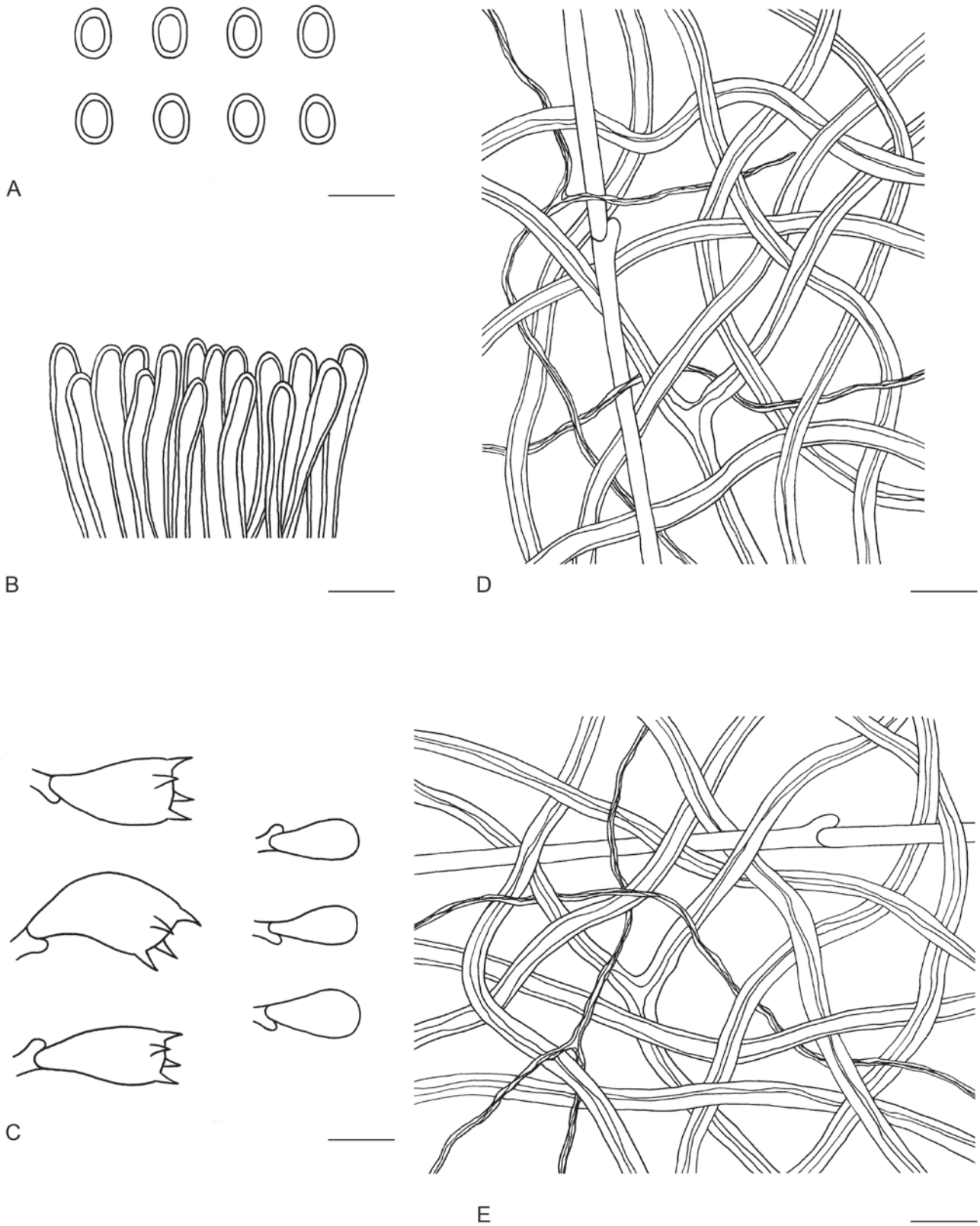

Fig. 18. Microscopic structures of *Ganoderma castaneum* (drawn from Cui 17283). **A.** Basidiospores. **B.** Apical cells from cuticle. **C.** Basidia and basidioles. **D.** Hyphae from trama. **E.** Hyphae from context. Scale bars = 10 µm.

Etymology: chuxiongense (*Lat.*), refers to the holotype of this species being found in Chuxiong City of Yunnan Province.

Typus: **China**, Yunnan, Chuxiong, Xishan Park, on stump of angiosperm tree, 25 Aug. 2018, Cui 17262 (**holotype** BJFC034120).

Description: *Basidiomata* annual, laterally stipitate, corky. *Pilei* solitary, flabelliform, dimidiate and lobate, up to 6 cm diam and 4 mm thick. *Pileal surface* reddish brown when fresh becoming dark-red when dry, laccate, glabrous, with concentric bands and slightly radial rugose; margin pale yellow, acute to obtuse, entire. *Pore surface* pale light-yellow when fresh, turning darker when bruised, buff to pale straw yellow when dry; pores circular, 4–6 per mm; dissepiments slightly thick, entire. *Context* dark wood brown, not obviously stratified, without black melanoid lines, soft corky, up to 2 mm thick. *Tubes* pale to dark wood brown, non-

Fig. 19. Basidiomata of *Ganoderma chuxiongense*.

stratified, up to 2 mm long. *Stipe* concolorous with pileal surface, cylindrical and solid, up to 7 cm long and 6 mm diam. *Hyphal system* trimitic; generative hyphae with clamp connections; all hyphae IKI –, CB +; tissues darkening in KOH. Generative hyphae in context colourless, thin-walled, 2–3 µm diam; skeletal hyphae in context pale yellow, thick-walled with a wide to narrow lumen or sub-solid, arboriform and flexuous, 2–4 µm diam; binding hyphae in context colourless, thick-walled, branched and flexuous, up to 2 µm diam. Generative hyphae in tubes colourless, thin-walled, 2–3 µm diam; skeletal hyphae in tubes pale yellow, thick-walled with a wide to narrow lumen or sub-solid, arboriform and flexuous, 2–4 µm diam; binding hyphae in tubes colourless, thick-walled, branched and flexuous, up to 1.5 µm diam. *Pileipellis* composed of clamped generative hyphae, slightly thick-walled, apical cells clavate, slightly inflated and flexuous, golden yellow, about 23–30 × 6–11 µm, forming a regular palisade. *Cystidia* and *cystidioles* absent. *Basidia* barrel-shaped, colourless, thin-walled, 15–20 × 10–12 µm; *basidioles* broadly clavate, colourless, thin-walled, 13–18 × 7–11 µm. *Basidiospores* broadly ellipsoid to ovoid, truncated, pale yellowish brown, IKI –, CB +, double-walled with distinctly thick walls, exospore wall smooth, endospore wall with dense spinules, (7.9–)8–9(–9.2) × (6–)6.2–7(–7.1) µm, L = 8.45 µm, W = 6.58 µm, Q = 1.28 (n = 60/1, with the turgid vesicular appendix excluded); (9.5–)10–11.3(–11.5) × (6.2–)6.5–7.3 µm, L = 10.35 µm, W = 6.88 µm, Q = 1.5 (n = 60/1, with the turgid vesicular appendix included).

Notes: *Ganoderma chuxiongense* is characterised by its stipitate basidiomata with lobate pilei, reddish brown pileal surface and pale-yellow pore surface when fresh. *Ganoderma kunmingense* described from Yunnan Province is like *G. chuxiongense* in the thin basidiomata with laccate and reddish brown pileal surface, margin entire or incised, but it has no concentric bands on the pileal surface, a cream pore surface, and broadly ellipsoid to subglobose basidiospores without obvious spinules on the endospore wall (Zhao 1989a).

Ganoderma cocoicola B.K. Cui, J.H. Xing & Y.F. Sun, ***sp. nov.*** MycoBank MB 839674. Figs 21, 22.

Diagnosis: Differs from other species in the genus by its small and hard basidiomata without stipe, dark and laccate pileal surface, homogeneous context, non-stratified tubes, oblong-ellipsoid and truncated basidiospores.

Etymology: *cocoicola* (*Lat.*), refers to this species growing on *Cocos*.

Typus: **Australia**, Queensland, Cairns, Cairns Botanical Garden, on stump of *Cocos*, 17 May 2018, Cui 16791 (**holotype** BJFC030090).

Additional material examined: **Australia**, Queensland, Cairns, Cairns Botanical Garden, on stump of *Cocos*, 17 May 2018, Cui 16792 (BJFC030091).

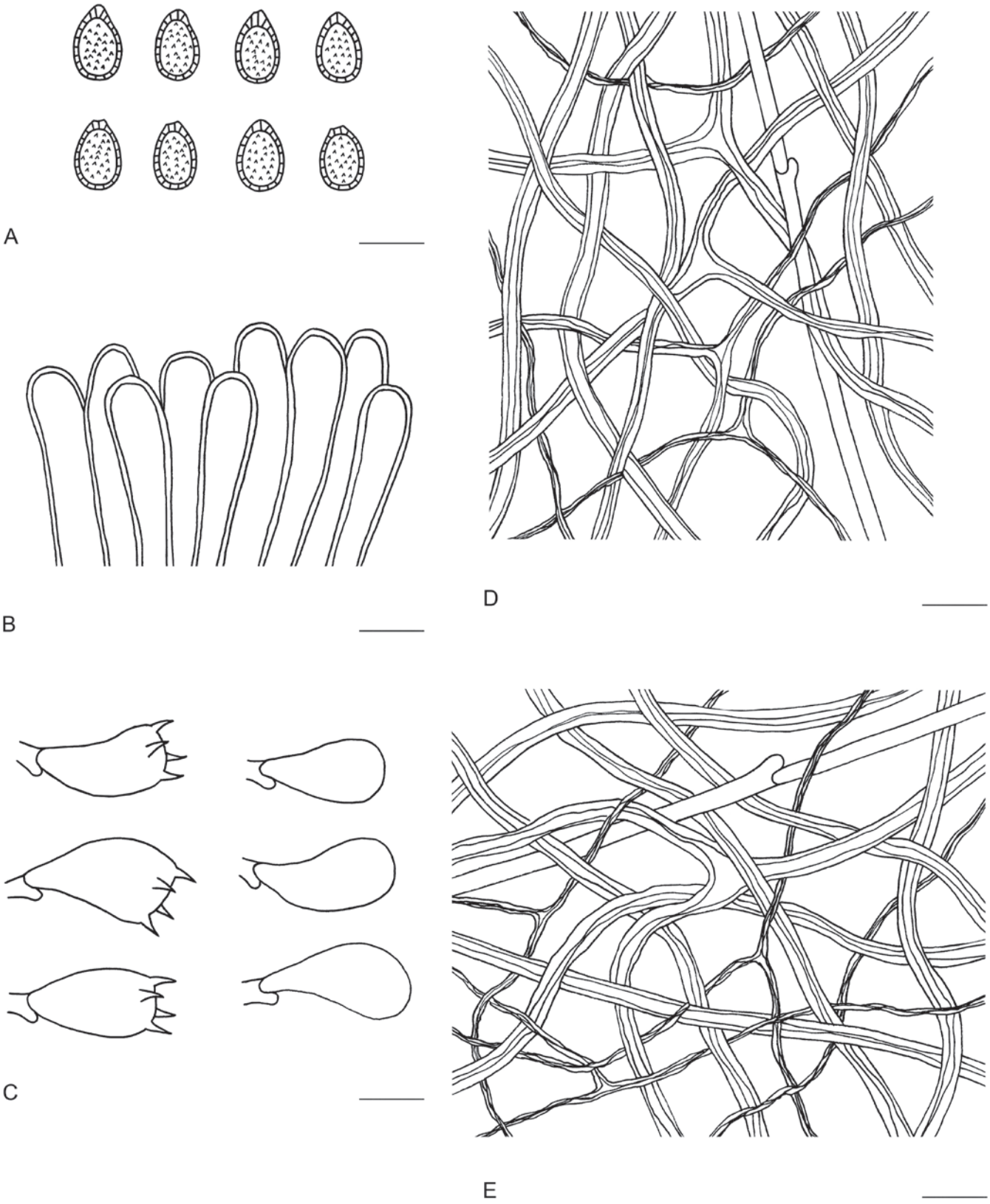

Fig. 20. Microscopic structures of *Ganoderma chuxiongense* (drawn from Cui 17262). **A.** Basidiospores. **B.** Apical cells from cuticle. **C.** Basidia and basidioles. **D.** Hyphae from trama. **E.** Hyphae from context. Scale bars = 10 µm.

Description: *Basidiomata* annual to perennial, sessile or sometimes sub-stipitate, hard corky to woody hard. *Pilei* solitary, flabelliform to ungulate, up to 3.5 cm diam and 1.5 cm thick. *Pileal surface* dark-red to near black, laccate, glabrous, with concentric furrows and slightly radial wrinkles; margin obtuse, entire. *Pore surface* white when fresh, turning darker when bruised, straw yellow to pale brown when dry; pores circular to angular, 4–6 per mm; dissepiments distinctly thick, entire. *Context* dark brown to cinnamon brown, homogeneous, without black melanoid lines, hard corky, up to 3 mm thick. *Tubes* dark grey to greyish brown, non-stratified, up to 1.2 cm long. *Hyphal system* trimitic; generative hyphae with clamp connections; all hyphae IKI –, CB +; tissues darkening in KOH. Generative hyphae in context colourless, thin-walled, 2–3 µm diam; skeletal hyphae in context pale yellowish brown, thick-walled

Fig. 21. Basidiomata of *Ganoderma cocoicola*.

with a wide to narrow lumen or sub-solid, frequently arboriform and flexuous, 2.5–5 µm diam; binding hyphae in context colourless, thick-walled, branched and flexuous, up to 2 µm diam. Generative hyphae in tubes colourless, thin-walled, 2–3 µm diam; skeletal hyphae in tubes pale yellowish brown, thick-walled with a wide to narrow lumen or sub-solid, frequently arboriform and flexuous, 3–5 µm diam; binding hyphae in tubes colourless, thick-walled, branched and flexuous, up to 1.5 µm diam. *Pileipellis* composed of clamped generative hyphae, thick-walled to sub-solid, apical cells clavate, flexuous, yellowish brown, about 27–35 × 5–7 µm, forming a regular palisade. *Cystidia* and *cystidioles* absent. *Basidia* broadly clavate, colourless, thin-walled, 16–22 × 7–10 µm; *basidioles* in shape like the basidia, colourless, thin-walled, 13–20 × 7–10 µm. *Basidiospores* oblong-ellipsoid, truncated, pale yellowish brown, IKI –, CB +, double-walled with moderately thick walls, exospore wall smooth, endospore wall with dense spinules, 9–9.8(–10) × 4.2–5.4(–5.6) µm, L = 9.42 µm, W = 4.77 µm, Q = 1.91–2.04 (n = 60/2, with the turgid vesicular appendix excluded); (9.6–)9.7–10.7(–10.8) × (4.2–)4.4–5.4(–5.5) µm, L = 10.15 µm, W = 4.83 µm, Q = 2.08–2.12 (n = 60/2, with the turgid vesicular appendix included).

Notes: *Ganoderma cocoicola* was collected from Australia on *Cocos*. It is characterised by small and hard basidiomata without a stipe, blackish brown and laccate pileal surface, homogeneous context, non-stratified tubes, oblong-ellipsoid and truncated basidiospores. In the phylogenetic analyses, *G. cocoicola* clustered with *G. zonatum*, *G. ryvardenii*, *G. boninense*, and *G. hochiminhense* with high support (Fig. 1); all these species grow on palm trees (Patouillard 1889, Murrill 1902, Kinge & Mih 2011, Zhou *et al.* 2015), except *G. hochiminhense* which grows on *Areca* (Luangharn *et al*. 2021).

Ganoderma fallax B.K. Cui, J.H. Xing & Vlasák, ***sp. nov.*** MycoBank MB 839677. Figs 23, 24.

Diagnosis: Differs from other species in the genus by its non-laccate pileal surface with faintly concentric furrows, stratified tubes, and basidiospores not obviously truncated with dense spinules on the endospore wall.

Etymology: *fallax* (*Lat.*), refers to this species being easily confused morphologically with other non-laccate species.

Typus: **USA**, Pennsylvania (**holotype** JV 1009/27).

Materials examined: **USA**, Arizona, JV 1209/60J (JV); New Jersey, JV 0109/B1-J (JV); Pennsylvania, JV 0709/39 (JV); Tennessee, JV 0509/93K, JV 1410/14J (JV).

Description: *Basidiomata* perennial, sessile, hard corky to woody hard. *Pilei* solitary, flabelliform to ungulate or shell-shaped, up to 11 cm diam and 3 cm thick. *Pileal surface* yellowish brown to dark brown, dull, glabrous, with faint concentric furrows; margin acute, entire, slightly wavy. *Pore surface* white to pale brown when fresh,

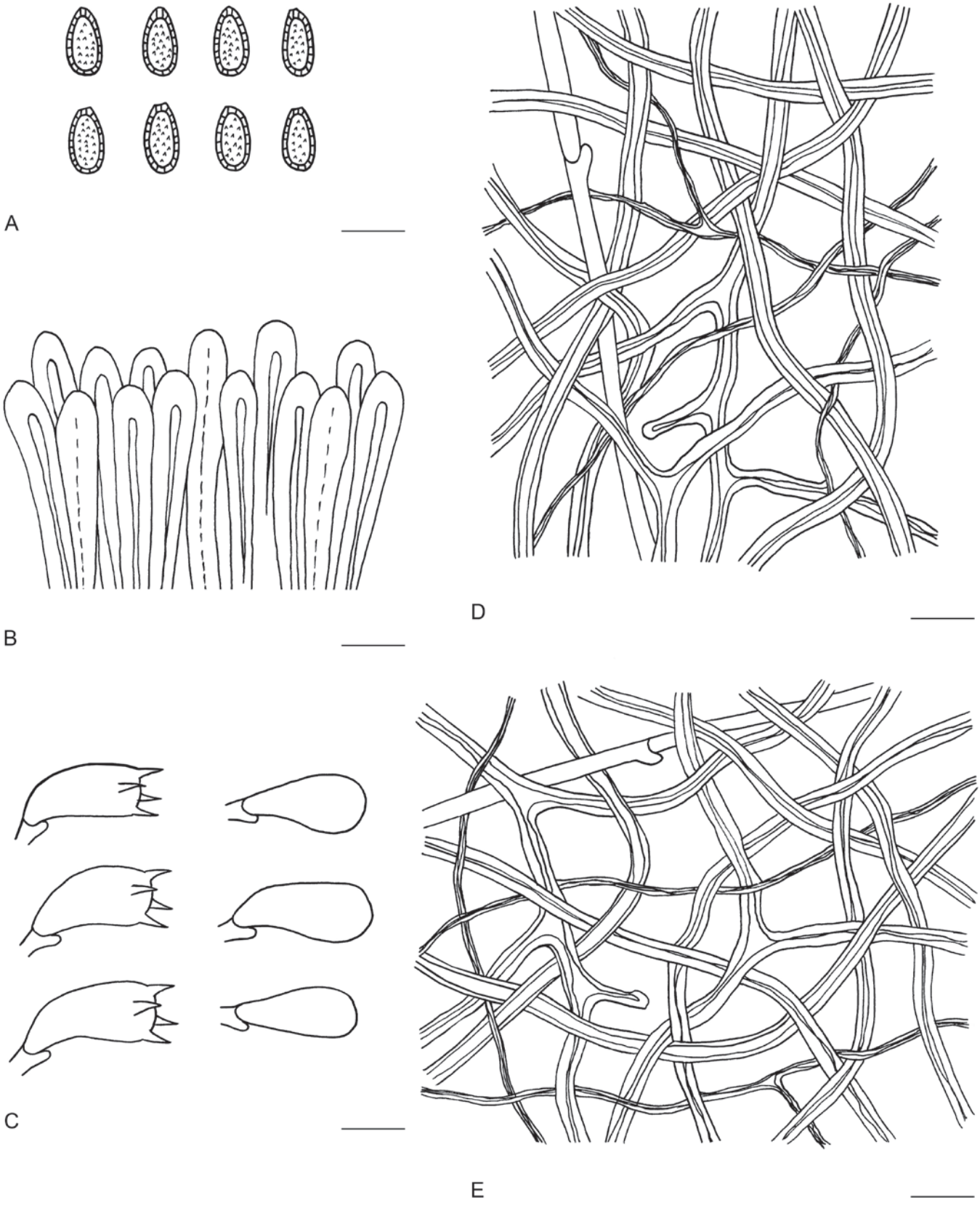

Fig. 22. Microscopic structures of *Ganoderma cocoicola* (drawn from Cui 16791). **A.** Basidiospores. **B.** Apical cells from cuticle. **C.** Basidia and basidioles. **D.** Hyphae from trama. **E.** Hyphae from context. Scale bars = 10 µm.

turning darker when bruised, straw yellow when dry; pores circular, 4–6 per mm; dissepiments slightly thick, entire. *Context* yellowish brown to dark brown, homogeneous, with black melanoid lines, corky, up to 7 mm thick. *Tubes* concolorous with context, stratified, up to 1.2 cm long. *Hyphal system* trimitic; generative hyphae with clamp connections; all hyphae IKI –, CB +; tissues darkening in KOH. Generative hyphae in context colourless, thin-walled, 2.5–5.5 µm diam; skeletal hyphae in context pale yellowish brown, thick-walled with narrow lumen or sub-solid, arboriform and flexuous, 3–6 µm diam; binding hyphae in context colourless, thick-walled, branched and flexuous, 2–3 µm diam. Generative hyphae in tubes colourless, thin-walled, 2–3.5 µm diam; skeletal hyphae in tubes

Fig. 23. Basidiomata of *Ganoderma fallax*.

pale brown, thick-walled with narrow lumen or sub-solid, arboriform and flexuous, 2–5 µm diam; binding hyphae in tubes colourless, thick-walled, branched and flexuous, 2–2.5 µm diam. *Cystidia* and *cystidioles* absent. *Basidia* barrel-shaped to clavate, colourless, thin-walled, 25–30 × 14–21 µm; *basidioles* in shape like the basidia, colourless, thin-walled, 16–17 × 9–18 µm. *Basidiospores* ovoid, not obviously truncated, pale yellowish brown, IKI –, CB +, double-walled with distinctly thick walls, exospore wall smooth, endospore wall with dense spinules, (8.5–)9–10(–10.5) × 6–7.5 µm, L = 9.25 µm, W = 6.56 µm, Q = 1.37 (n = 30/1, with the turgid vesicular appendix included).

Notes: *Ganoderma fallax* may be confused with the non-laccate species *G. adspersum*, which has large basidiomata with a yellowish brown pileal surface, homogeneous context and stratified tubes, but *G. adspersum* has larger and more obviously truncated basidiospores, and lacks concentric ornamentation on the pileal surface. In the phylogenetic analyses, *G. fallax* formed an independent lineage then clustered with *G. adspersum* (Fig. 1).

Ganoderma guangxiense B.K. Cui, J.H. Xing & Y.F. Sun, ***sp. nov.*** MycoBank MB 839678. Figs 25, 26.

Diagnosis: Differs from other species in the genus by its sessile basidiomata, greyish brown to near black pileal surface with obvious concentric furrows, cracked when dry, homogeneous context, non-stratified tubes, ellipsoid to ovoid and truncated basidiospores.

Etymology: *guangxiense* (*Lat.*), refers to the holotype of this species located at Guangxi.

Typus: **China**, Guangxi, Tianlin County, Cenwanglaoshan Nature Reserve, on stump of angiosperm tree, 8 Jul. 2017, Cui 14453 (**holotype** BJFC029321).

Additional materials examined: **China**, Guangxi, Tianlin County, Cenwanglaoshan Nature Reserve, on stump of angiosperm tree, 8 Jul. 2017, Cui 14454 (BJFC029322), Cui 14455 (BJFC029323); Jinxiu County, Dayaoshan Nature Reserve, on fallen trunk of angiosperm tree, 15 Jul. 2017, Cui 14500 (BJFC029369), Cui 14508 (BJFC029377).

Description: *Basidiomata* annual, sessile and broadly attached, hard corky to woody hard. *Pilei* solitary, flabelliform to shell-shaped, up to 11 cm diam and 4.3 cm thick. *Pileal surface* greyish brown to near black when fresh, dull, glabrous, with obvious concentric furrows, cracked when dry; margin obtuse, entire. *Pore surface* cream when

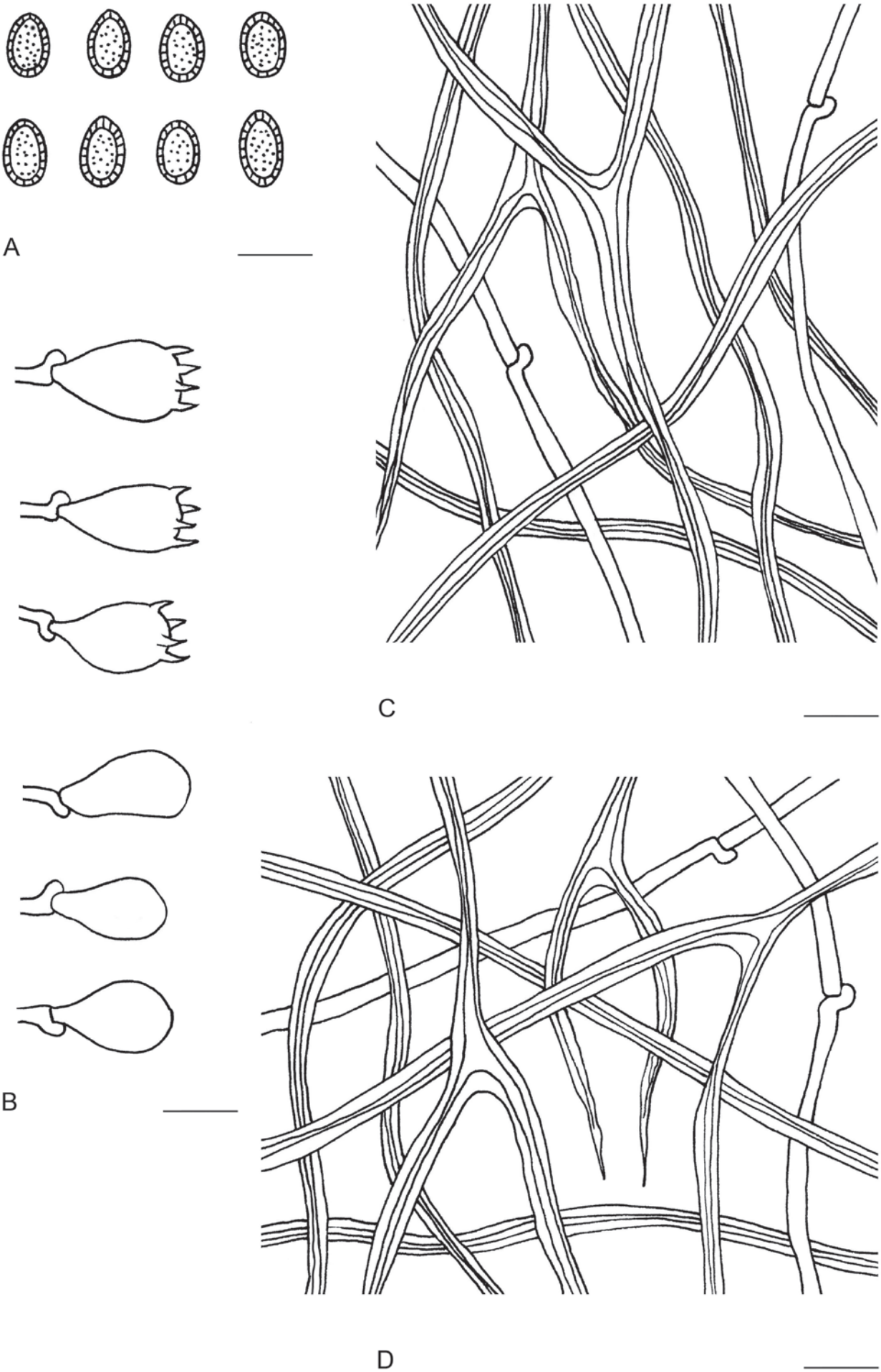

Fig. 24. Microscopic structures of *Ganoderma fallax* (drawn from JV 1009/27). **A.** Basidiospores. **B.** Basidia and basidioles. **C.** Hyphae from trama. **D.** Hyphae from context. Scale bars = 10 µm.

Fig. 25. Basidiomata of *Ganoderma guangxiense*.

fresh, turning darker when bruised, dark straw yellow to pale brown when dry; pores circular, 5–7 per mm; dissepiments moderately thick, entire. *Context* dark brown to cinnamon brown, homogeneous, with black melanoid lines, hard corky, up to 3 cm thick. *Tubes* slightly paler than context, non-stratified, up to 2 cm long. *Hyphal system* trimitic; generative hyphae with clamp connections; all hyphae IKI –, CB +; tissues darkening in KOH. Generative hyphae in context colourless, thin-walled, 2–3 µm diam; skeletal hyphae in context reddish brown, thick-walled with a wide to narrow lumen or sub-solid, arboriform and flexuous, 2–6 µm diam; binding hyphae in context colourless, thick-walled, branched and flexuous, up to 2 µm diam. Generative hyphae in tubes colourless, thin-walled, 2–3 µm diam; skeletal hyphae in tubes reddish brown, thick-walled with a wide to narrow lumen or sub-solid, arboriform and flexuous, 2–4 µm diam; binding hyphae in tubes colourless, thick-walled, branched and flexuous, up to 2 µm diam. *Pileipellis* composed of clamped generative hyphae, thick-walled to sub-solid, apical cells clavate, inflated and flexuous, golden yellow, about 28–37 × 5–8 µm, forming a regular palisade. *Cystidia* and *cystidioles* absent. *Basidia* barrel-shaped, colourless, thin-walled, 15–20 × 7–11 µm; *basidioles* broadly clavate, colourless, thin-walled, 12–15 × 7–9 µm. *Basidiospores* ellipsoid to ovoid, truncated, yellowish brown, IKI –, CB +, double-walled with moderately thick walls, exospore wall smooth, endospore wall with dense spinules, (7.5–)7.8–8.8(–8.9) × (4.9–)5–6(–6.5) µm, L = 8.23 µm, W = 5.49 µm, Q = 1.47–1.53 (n = 60/2, with the turgid vesicular appendix excluded); 8.7–9.8(–10) × (4.9–)5–6(–6.1) µm, L = 9.23 µm, W = 5.52 µm, Q = 1.67–1.68 (n = 60/2, with the turgid vesicular appendix included).

Notes: Morphologically, *Ganoderma guangxiense* is very similar to *G. australe* and they are not easy to separate. However, phylogenetically, *G. guangxiense* and *G. australe* are divided into two independent lineages with good support (Fig. 1). *Ganoderma daiqingshanense* also has sessile and hard basidiomata with blackish pilei, but it differs from *G. guangxiense* by having a heterogeneous context, larger pores (4–5 per mm) and irregular palisade of pileipellis structure (Zhao 1989a).

Ganoderma puerense B.K. Cui, J.H. Xing & Y.F. Sun, ***sp. nov.*** MycoBank MB 839679. Figs 27, 28.

Diagnosis: Differs from other species in the genus by its woody hard and thin basidiomata, yellowish brown pileal surface with dense concentric black bands or furrows, and a margin lacerated like petals.

Etymology: *puerense* (*Lat.*), refers to this species being collected from Puer City of Yunnan Province.

Typus: **China**, Yunnan, Puer, Puer Forest Park, on living tree of *Cinnamomum*, 17 Aug. 2019, Dai 20427 (**holotype** BJFC032095).

Description: *Basidiomata* annual, sessile or with short stipe, usually growing together, imbricate, woody hard. *Pilei* solitary, sub-orbicular to flabelliform, applanate, up to 7.5 cm diam and 8 mm thick. *Pileal surface* yellowish brown to dark brown, dull,

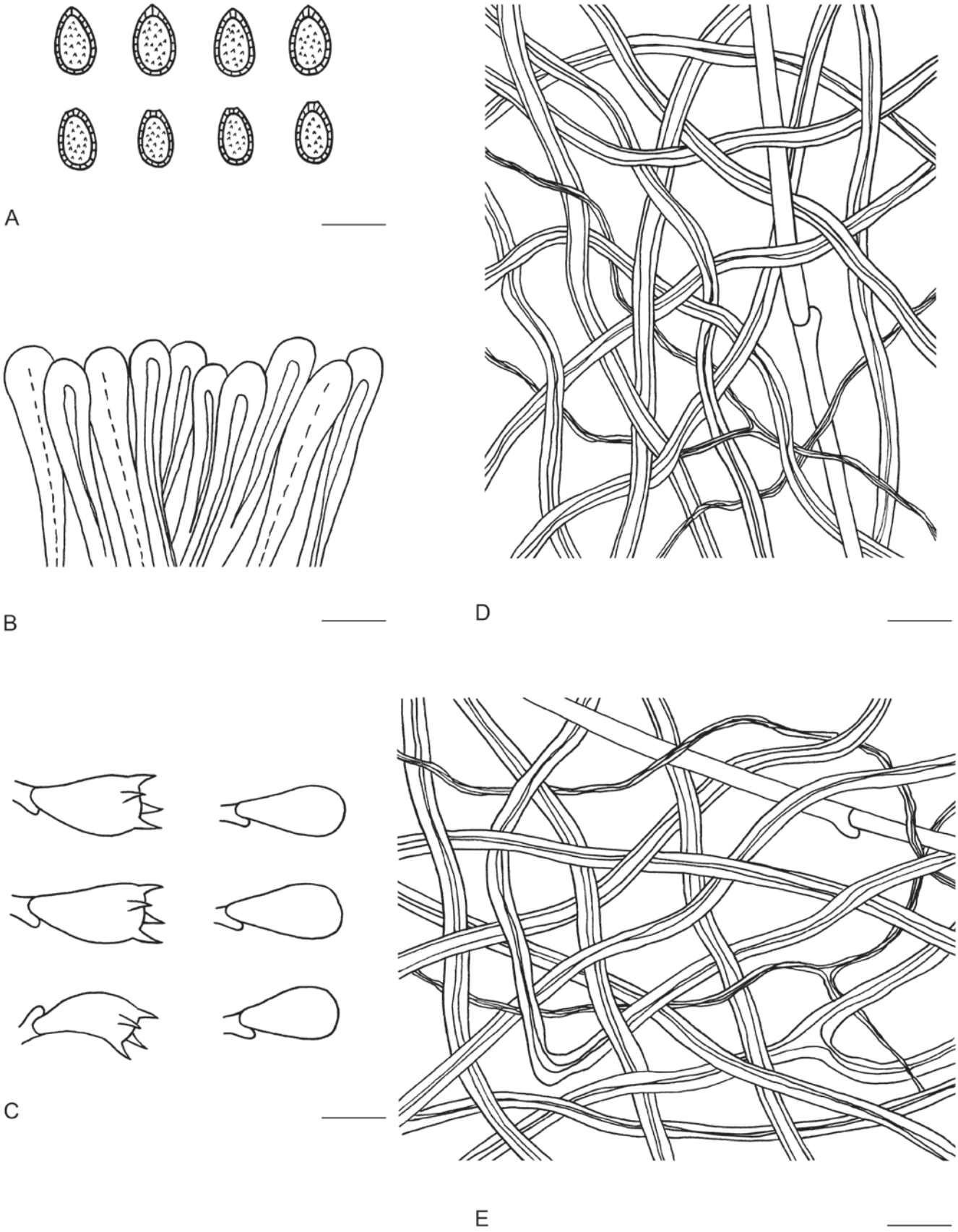

Fig. 26. Microscopic structures of *Ganoderma guangxiense* (drawn from Cui 14453). **A.** Basidiospores. **B.** Apical cells from cuticle. **C.** Basidia and basidioles. **D.** Hyphae from trama. **E.** Hyphae from context. Scale bars = 10 µm.

glabrous, with dense concentric black bands or furrows and slightly radial wrinkles; margin acute to obtuse, lacerated like petals. *Pore surface* white when fresh, turning darker when bruised, buff to pale brown when dry; pores circular to angular, 5–7 per mm; dissepiments moderately thick, entire. *Context* straw yellow to dark brown, homogeneous, with black melanoid lines, hard corky, up to 3 mm thick. *Tubes* dark brown, non-stratified, up to 5 mm long. *Stipe* concolorous with pileal surface, cylindrical

Fig. 27. Basidiomata of *Ganoderma puerense*.

and solid, up to 1.5 cm long and 3 mm diam. *Hyphal system* trimitic; generative hyphae with clamp connections; all hyphae IKI –, CB +; tissues darkening in KOH. Generative hyphae in context colourless, thin-walled, 2–3 µm diam; skeletal hyphae in context pale yellowish brown, thick-walled with a wide to narrow lumen or sub-solid, frequently arboriform and flexuous, 2–5 µm diam; binding hyphae in context colourless, thick-walled, rarely branched and flexuous, 1–2 µm diam. Generative hyphae in tubes colourless, thin-walled, 2–3 µm diam; skeletal hyphae in tubes pale yellowish brown, thick-walled with a wide to narrow lumen or sub-solid, arboriform and flexuous, 2–4 µm diam; binding hyphae in tubes colourless, thick-walled, rarely branched and flexuous, 1–2 µm diam. *Pileipellis* composed of clamped generative hyphae, thick-walled to sub-solid, apical cells clavate, faintly inflated and flexuous, yellowish brown, about 25–40 × 5–7 µm, forming a regular palisade. *Cystidia* and *cystidioles* absent. *Basidia* barrel-shaped, colourless, thin-walled, 12–20 × 7–10 µm; *basidioles* clavate to fusiform, colourless, thin-walled, 11–18 × 7–10 µm. *Basidiospores* ellipsoid to ovoid, truncated, yellowish brown, IKI –, CB +, double-walled with slightly thick walls, exospore wall smooth, endospore wall with dense spinules, (7–)7.2–8.5(–8.8) × (4.8–)5–6(–6.4) µm, L = 7.83 µm, W = 5.31 µm, Q = 1.47 (n = 60/1, with the turgid vesicular appendix excluded); (8.5–)8.8–9.5(–9.8) × (4.8–)5–6.2(–6.8) µm, L = 9.1 µm, W = 5.52 µm, Q = 1.65 (n = 60/1, with the turgid vesicular appendix included).

Notes: *Ganoderma bicharacteristicum* also has a dull pileal surface, homogeneous context and was described from Yunnan Province, but *G. bicharacteristicum* can be distinguished from *G. puerense* by its stipitate basidiomata with black pileal surface, wood brown pore surface and subglobose basidiospores (6.3–9 × 5.6–8.7 µm, Zhang 1994).

Ganoderma subangustisporum B.K. Cui, J.H. Xing & Y.F. Sun, ***sp. nov.*** MycoBank MB 839680. Figs 29, 30.

Diagnosis: Differs from other species in the genus by its dark-red to near black pileal surface with concentric bands and radial rugosities made by dark and continuous spots, margin acute and thin, and ellipsoid basidiospores with truncated apex.

Etymology: *subangustisporum* (*Lat.*), refers to this species being closely related to *Ganoderma angustisporum*.

Typus: **China**, Yunnan, Pingbian County, Daweishan National Nature Reserve, on stump of angiosperm tree, 3 Aug. 2019, Cui 18592 (**holotype** BJFC035453).

Materials examined: **China**, Yunnan, Pingbian County, Daweishan National Nature Reserve, on stump of angiosperm tree, 3 Aug. 2019, Cui 18593 (BJFC035454), Cui 18594 (BJFC035455), Cui 18595 (BJFC035456), Cui 18596 (BJFC035457), Cui 18597 (BJFC035458).

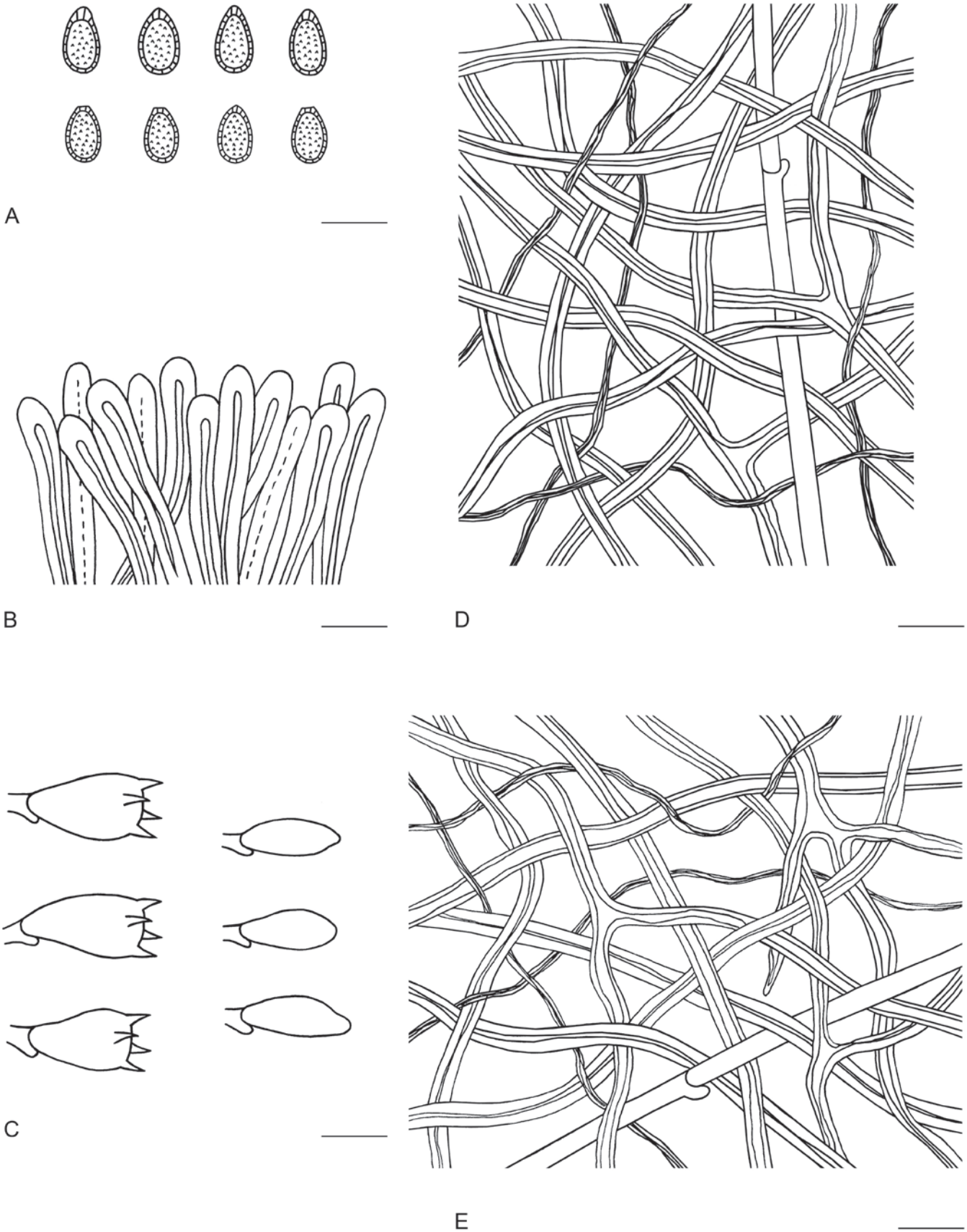

Fig. 28. Microscopic structures of *Ganoderma puerense* (drawn from Dai 20427). **A.** Basidiospores. **B.** Apical cells from cuticle. **C.** Basidia and basidioles. **D.** Hyphae from trama. **E.** Hyphae from context. Scale bars = 10 µm.

Description: *Basidiomata* annual, sessile or with short and lateral stipe, hard corky. *Pilei* solitary, sub-circular to flabelliform, up to 8 cm diam and 1.6 cm thick. *Pileal surface* dark reddish brown, laccate, glabrous, with concentric bands and radial rugose made by dark and continuous spots; margin acute, thin, entire. *Pore surface* white when fresh, turning darker when bruised, buff to pale straw yellow when dry; pores circular to angular, 4–6 per mm; dissepiments slightly thick, entire. *Context* cinnamon brown, homogeneous, with pale melanoid lines, hard corky, up to 9 mm thick. *Tubes* pale brown, non-stratified, up to 9 mm long. *Stipe*

Fig. 29. Basidiomata of *Ganoderma subangustisporum*.

concolourous with pileal surface, cylindrical and solid, up to 1 cm long and 1.5 cm diam. *Hyphal system* trimitic; generative hyphae with clamp connections; all hyphae IKI –, CB +; tissues darkening in KOH. Generative hyphae in context colourless, thin-walled, 3–4 µm diam; skeletal hyphae in context yellowish brown, thick-walled with a wide to narrow lumen or sub-solid, arboriform and flexuous, 3–5 µm diam; binding hyphae in context colourless, thick-walled, branched and flexuous, up to 2 µm diam. Generative hyphae in tubes colourless, thin-walled, 3–4 µm diam; skeletal hyphae in tubes yellowish brown, thick-walled with a wide to narrow lumen or sub-solid, arboriform and flexuous, 2–5 µm diam; binding hyphae in tubes colourless, thick-walled, branched and flexuous, up to 2 µm diam. *Pileipellis* composed of clamped generative hyphae, thick-walled to sub-solid, apical cells clavate, inflated and flexuous, dark yellowish brown to reddish brown, about 32–50 × 7–12 µm, forming a regular palisade. *Cystidia* and *cystidioles* absent. *Basidia* barrel-shaped, colourless, thin-walled, 13–19 × 10–13 µm; *basidioles* broadly clavate, colourless, thin-walled, 13–18 × 6–12 µm. *Basidiospores* broadly ellipsoid to ellipsoid, truncated, yellowish brown, IKI –, CB +, double-walled with distinctly thick walls, exospore wall smooth, endospore wall with dense spinules, 10–11.8(–12.1) × (5–)5.1–7(–7.3) µm, L = 10.88 µm, W = 6.13 µm, Q = 1.72–1.84 (n = 60/2, with the turgid vesicular appendix excluded); (10.3–)10.7–12.8(–13.1) × (5–)5.2–7(–7.3) µm, L = 11.72 µm, W = 6.02 µm, Q = 1.93–1.97 (n = 60/2, with the turgid vesicular appendix included).

Notes: *Ganoderma subangustisporum* clusters with *G. angustisporum* with high support in the phylogenetic analyses (Fig. 1). Morphologically, *G. angustisporum* differs from *G. subangustisporum* by having large basidiomata with lacerated margin, darker pileal surface with concentric furrows, and narrower basidiospores (9–11.3 × 4–5.2 µm, Xing *et al.* 2018).

Ganoderma subellipsoideum B.K. Cui, J.H. Xing & Y.F. Sun, ***sp. nov.*** MycoBank MB 839681. Figs 31, 32.

Diagnosis: Differs from other species in the genus by its subsessile and hard basidiomata, dark yellowish brown to blackish pileal surface with dense concentric furrows, small pores and stratified tubes, and ellipsoid basidiospores with truncated apex.

Etymology: *subellipsoideum* (*Lat.*), refers to this species being closely related to *Ganoderma ellipsoideum*.

Typus: **Malaysia**, Kuala Lumpur, Ecological Forest Park, on fallen trunk of angiosperm tree, 8 Dec. 2019, Cui 18325 (**holotype** BJFC035184).

Additional materials examined: **Malaysia**, Selangor, Kota Damansara, National Forest Reserve, on fallen trunk of angiosperm tree, 6 Dec. 2019, Cui 18241 (BJFC035100); Kuala Lumpur, Ecological Forest Park, on fallen trunk of angiosperm tree, 8 Dec. 2019, Cui 18327(BJFC035186).

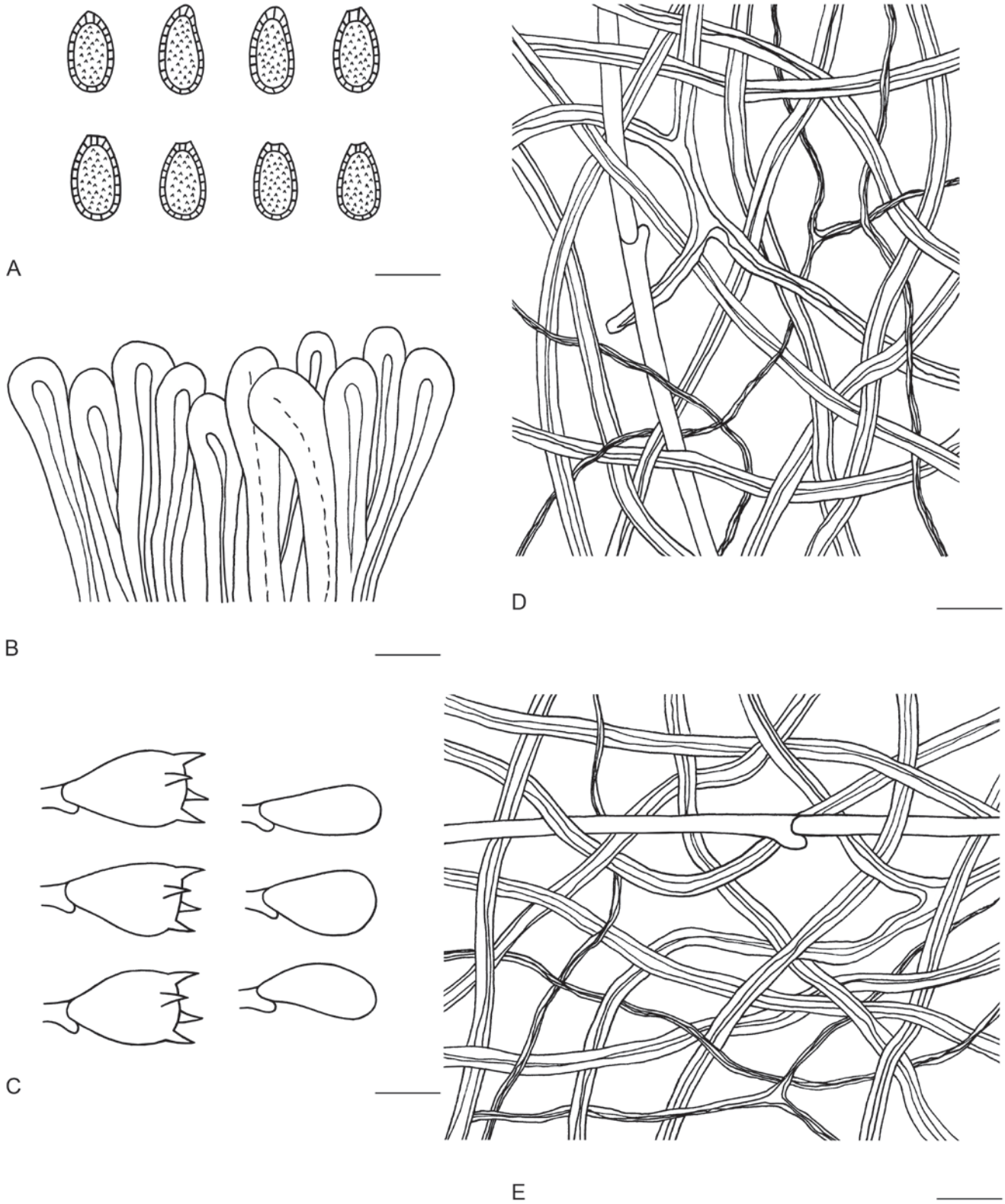

Fig. 30. Microscopic structures of *Ganoderma subangustisporum* (drawn from Cui 18592). **A.** Basidiospores. **B.** Apical cells from cuticle. **C.** Basidia and basidioles. **D.** Hyphae from trama. **E.** Hyphae from context. Scale bars = 10 µm.

Description: *Basidiomata* annual, sessile or with short and lateral stipe, woody hard. *Pilei* solitary, sub-circular to flabelliform, applanate, up to 9.5 cm diam and 2 cm thick. *Pileal surface* dark yellowish brown to near black when fresh becoming yellowish brown or greyish brown when dry, slightly laccate when fresh becoming dull when dry, glabrous, with dense concentric furrows; margin obtuse, entire. *Pore surface* white when fresh, turning darker when bruised, cream to buff when dry; pores circular, 6–8 per mm; dissepiments moderately thick, entire. *Context* cinnamon brown, homogeneous, with black melanoid lines, hard corky, up to 1 cm thick. *Tubes* dark brown, stratified by a layer of context, up to 9 mm long. *Stipe* concolourous with pileal surface, cylindrical and solid, up to 1.2 cm long and 1.3 cm diam. *Hyphal system* trimitic; generative hyphae with clamp connections; all hyphae IKI –, CB +; tissues darkening in KOH. Generative hyphae in context colourless, thin-walled, 2–4 µm diam; skeletal hyphae in context

Fig. 31. Basidiomata of *Ganoderma subellipsoideum*.

pale brown, thick-walled with a wide to narrow lumen or sub-solid, arboriform and flexuous, 2–5 µm diam; binding hyphae in context colourless, thick-walled, branched and flexuous, up to 1.5 µm diam. Generative hyphae in tubes colourless, thin-walled, 2–3 µm diam; skeletal hyphae in tubes yellowish brown, thick-walled with a wide to narrow lumen or sub-solid, arboriform and flexuous, 2–4 µm diam; binding hyphae in tubes colourless, thick-walled, branched and flexuous, up to 1 µm diam. *Pileipellis* composed of clamped generative hyphae, thick-walled, apical cells clavate, flexuous, pale yellowish brown, about 30–40 × 3–5 µm, forming a regular palisade. *Cystidia* and *cystidioles* absent. *Basidia* barrel-shaped, colourless, thin-walled, 12–17 × 9–11 µm; *basidioles* broadly clavate, colourless, thin-walled, 11–15 × 6–10 µm. *Basidiospores* ellipsoid, truncated, yellowish brown, IKI –, CB +, double-walled with moderately thick walls, exospore wall smooth, endospore wall with dense spinules, 6–6.9(–7) × 4–5.3(–5.5) µm, L = 6.46 µm, W = 4.62 µm, Q = 1.36–1.44 (n = 60/2, with the turgid vesicular appendix excluded); (8–)8.2–9.6(–10) × (4–)4.2–5.2(–6) µm, L = 8.89 µm, W = 4.69 µm, Q = 1.89–1.9 (n = 60/2, with the turgid vesicular appendix included).

Notes: In the phylogenetic analyses, *G. subellipsoideum* is closely related to *G. ellipsoideum*. *Ganoderma ellipsoideum* was described from Hainan Province and it has a yellowish brown pileal surface with alternating brownish orange to yellowish brown zones, heterogeneous context and non-stratified tubes, and ellipsoid basidiospores of smaller size (6.1–7.3 × 3.7–4.6 µm, Hapuarachchi *et al.* 2018b) which make it different from *G. subellipsoideum*.

Ganoderma subflexipes B.K. Cui, J.H. Xing & Y.F. Sun, ***sp. nov.*** MycoBank MB 839675. Figs 33, 34.

Diagnosis: Differs from other species in the genus by its small and dorso-laterally stipitate basidiomata, dark yellow to orange-brown and laccate pileal surface, wavy margin, and obviously truncated basidiospores.

Etymology: *subflexipes* (*Lat.*), refers to this species being closely related to *Ganoderma flexipes*.

Typus: **China**, Guangdong, Renhua County, Danxiashan Nature Reserve, on stump of angiosperm tree, 4 Jun. 2019, Cui 17257 (**holotype** BJFC034115).

Additional materials examined: **China**, Guangdong, Renhua County, Danxiashan Nature Reserve, on root of angiosperm tree, 4 Jun. 2019, Cui 17247 (BJFC034105); on stump of angiosperm tree, 4 Jun. 2019, Cui 17258 (BJFC034116); Jiangxi, Shangrao, Daomaoshan Park, on the ground of *Cyclobalanopsis jenseniana*, 30 Aug. 2021, Dai 23665 (BJFC038237).

Description: *Basidiomata* annual, dorso-laterally stipitate, hard corky. *Pilei* solitary, flabelliform to shell-shaped, up to 3 cm diam and 1 cm thick. *Pileal surface* dark yellow to orange-brown, laccate, glabrous, with concentric bands and slightly radial rugose; margin obtuse, entire, wavy when fresh, incurved when dry. *Pore surface* buff to straw yellow when dry; pores circular to angular, 5–7 per mm; dissepiments slightly thick to moderately thick, entire. *Context*

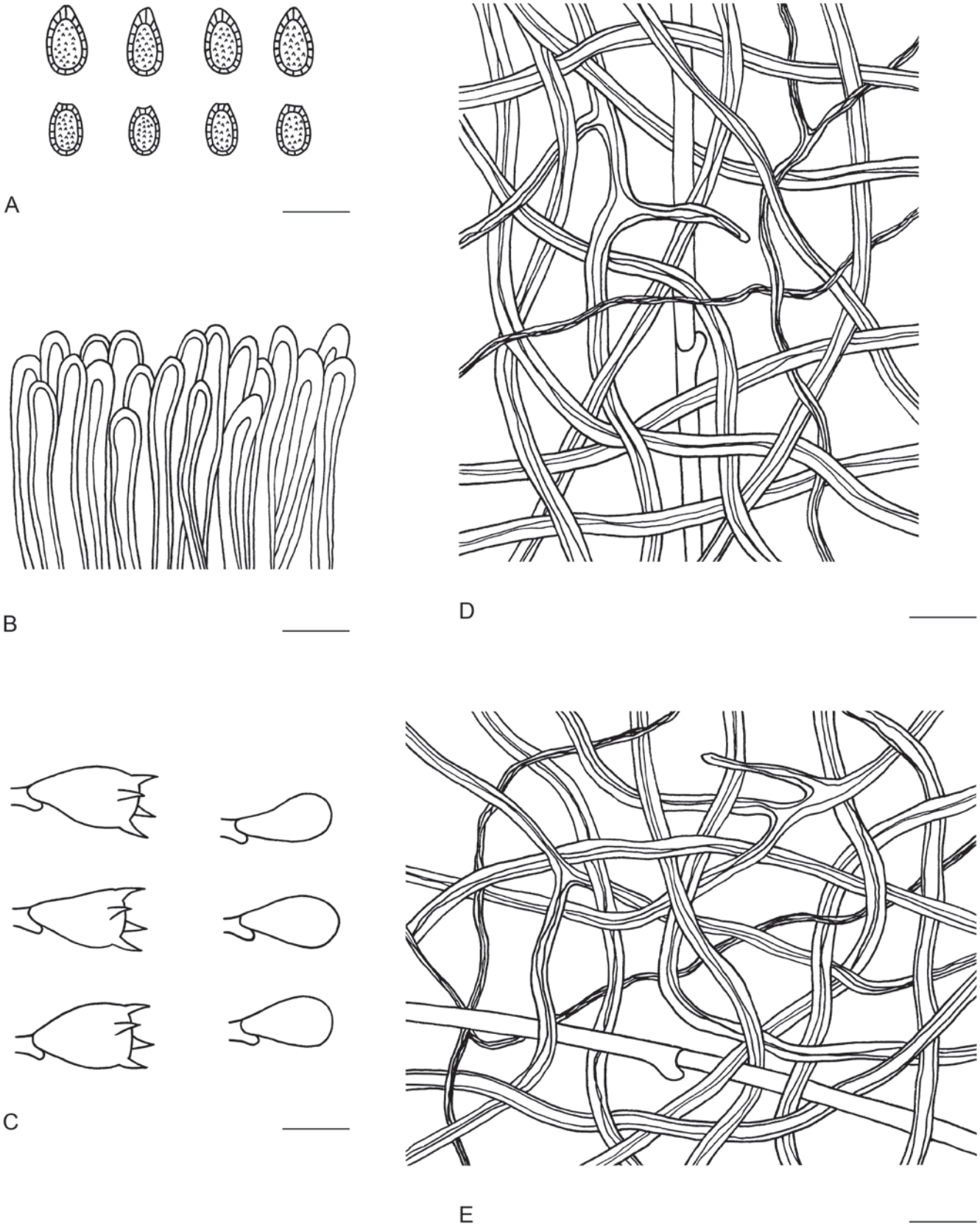

Fig. 32. Microscopic structures of *Ganoderma subellipsoideum* (drawn from Cui 18325). **A.** Basidiospores. **B.** Apical cells from cuticle. **C.** Basidia and basidioles. **D.** Hyphae from trama. **E.** Hyphae from context. Scale bars = 10 µm.

yellowish brown, homogeneous, without black melanoid lines, soft corky, up to 1.6 mm thick. *Tubes* buff, non-stratified, up to 7 mm long. *Stipe* dark-red, cylindrical and solid, sometimes budding without pilei, up to 14cm long and 6 mm diam. *Hyphal system* trimitic; generative hyphae with clamp connections; all hyphae IKI –, CB +; tissues darkening in KOH. Generative hyphae in context colourless, thin-walled, 2–3 µm diam; skeletal hyphae in context pale yellow, thick-walled with a wide to narrow lumen or sub-solid, arboriform and flexuous, 2–5 µm diam; binding hyphae in context colourless, thick-walled, branched and flexuous, up to 2 µm diam. Generative hyphae in tubes colourless, thin-walled, 2–3 µm diam; skeletal hyphae in tubes pale yellow, thick-walled with a wide to

Fig. 33. Basidiomata of *Ganoderma subflexipes*.

narrow lumen or sub-solid, arboriform and flexuous, 2–4 µm diam; binding hyphae in tubes colourless, thick-walled, branched and flexuous, up to 2 µm diam. *Pileipellis* composed of clamped generative hyphae, thick-walled to sub-solid, apical cells clavate, slightly inflated and flexuous, golden yellow, about 27–35 × 4–8 µm, forming a regular palisade. *Cystidia* and *cystidioles* absent. *Basidia* barrel-shaped, colourless, thin-walled, 15–22 × 9–11 µm; *basidioles* broadly clavate, colourless, thin-walled, 14–18 × 7–10 µm. *Basidiospores* ellipsoid to ovoid, truncated, yellowish brown, IKI –, CB +, double-walled with distinctly thick walls, exospore wall smooth, endospore wall with dense spinules, (6.3–)6.7–9.8(–10.1) × (4–)4.2–6.5(–7) µm, L = 8.2 µm, W = 5.37 µm, Q = 1.53–1.65 (n = 60/2, with the turgid vesicular appendix excluded); (7.6–)7.8–11(–11.5) × (4–)4.2–6.6(–6.8) µm, L = 9.25 µm, W = 5.46 µm, Q = 1.64–1.74 (n = 60/2, with the turgid vesicular appendix included).

Notes: *Ganoderma subflexipes* is distinguished by its small and dorso-laterally stipitate basidiomata, dark yellow to orange-brown pileal surface, wavy margin, and obviously truncated basidiospores. *Ganoderma flexipes* is sister to *G. subflexipes* in phylogenetic tree (Fig. 1), that species also has small and dorso-laterally stipitate basidiomata with a laccate pileal surface, but it differs from *G. subflexipes* by its reddish brown pileal surface, round and smooth margin, and basidiospores not obviously truncated (Steyaert 1972, Ryvarden 1983, Wang & Wu 2014).

Ganoderma sublobatum B.K. Cui, J.H. Xing & Y.F. Sun, ***sp. nov.*** MycoBank MB 839682. Figs 35, 36.

Diagnosis: Differs from other species in the genus by its annual basidiomata, non-laccate pileal surface with shallow concentric furrows and radial rugose, homogeneous context, non-stratified tubes and ellipsoid basidiospores with truncated apex.

Etymology: *sublobatum* (*Lat.*), refers to this species being closely related to *Ganoderma lobatum*.

Typus: **Australia**, Queensland, Cairns, Mount Whitfield Conservation Park, on stump of angiosperm tree, 18 May 2018, Cui 16804 (**holotype** BJFC030103).

Additional materials examined: **Australia**, Queensland, Cairns, Mount Whitfield Conservation Park, on stump of angiosperm tree, 18 May 2018, Cui 16805 (BJFC030104), Cui 16806 (BJFC030105).

Description: *Basidiomata* annual, sessile or subsessile, hard corky to woody hard. *Pilei* solitary, flabelliform to reniform or shell-shaped, applanate, up to 8 cm diam and 7 cm thick. *Pileal surface* pale brown to dark brown, dull, glabrous, with shallowly concentric furrows and radial rugose; margin obtuse, entire. *Pore surface* white to pale brown when fresh, turning darker when bruised, pale grey when

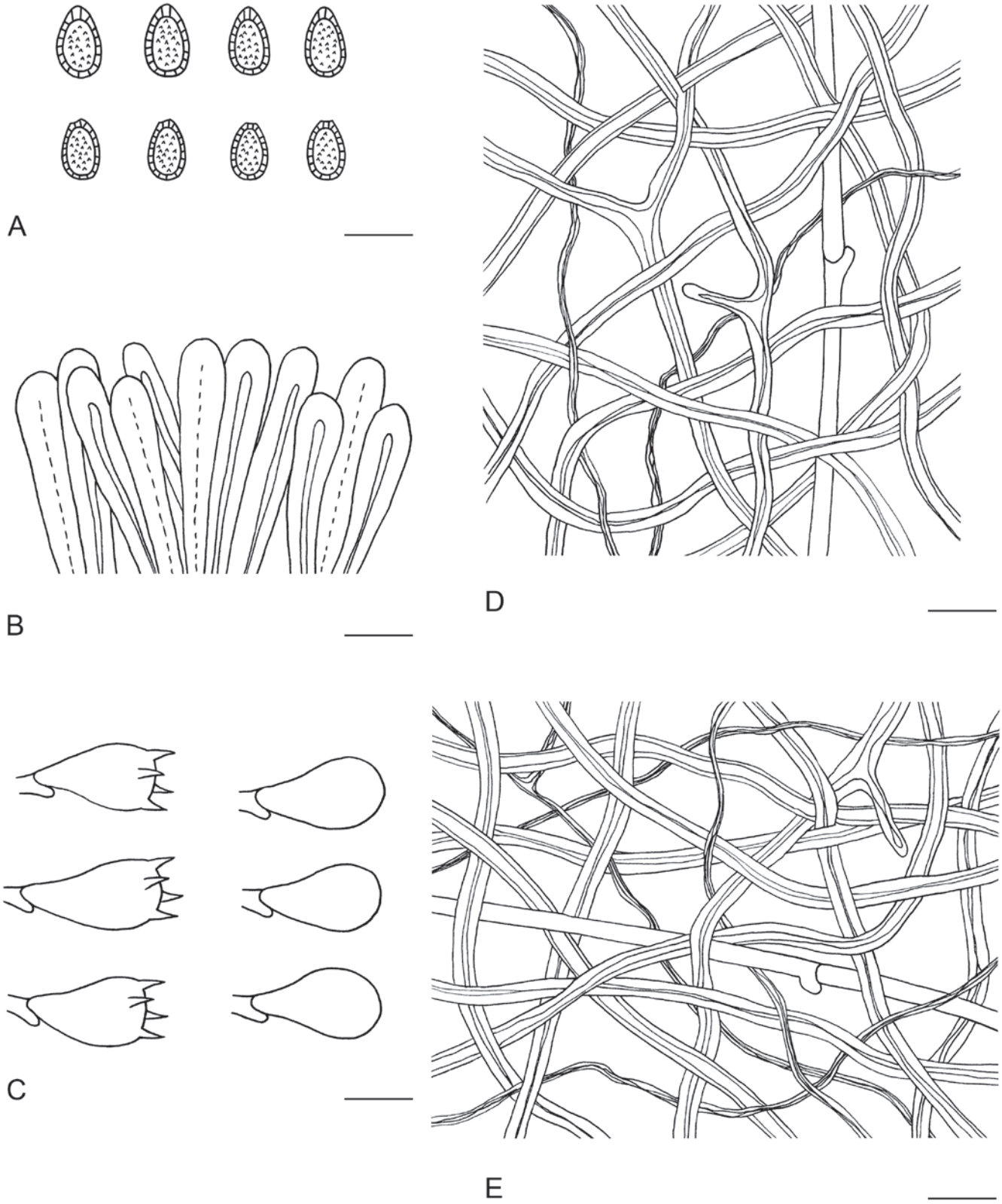

Fig. 34. Microscopic structures of *Ganoderma subflexipes* (drawn from Cui 17257). **A.** Basidiospores. **B.** Apical cells from cuticle. **C.** Basidia and basidioles. **D.** Hyphae from trama. **E.** Hyphae from context. Scale bars = 10 µm.

dry; pores circular, 5–6 per mm; dissepiments moderately thick, entire. *Context* dark brown, homogeneous, with black melanoid lines, corky, up to 3 mm thick. *Tubes* dark brown, non-stratified, up to 7 mm long. *Hyphal system* trimitic; generative hyphae with clamp connections; all hyphae IKI –, CB +; tissues darkening in KOH. Generative hyphae in context colourless, thin-walled, 2.5–5 µm diam; skeletal hyphae in context pale brown, thick-walled with narrow lumen or sub-solid, arboriform and flexuous, 3.5–6.5 µm diam; binding hyphae in context colourless, thick-walled, branched and flexuous, 2–3 µm diam. Generative hyphae in tubes colourless, thin-walled, 2–3.5 µm diam; skeletal hyphae in tubes pale brown, thick-walled with narrow lumen or sub-solid, arboriform and flexuous, 2–4.5 µm diam; binding hyphae in tubes colourless, thick-walled, branched and flexuous, 1.2–2.5 µm diam. *Pileipellis* composed of clamped generative hyphae, thin to slightly thick-walled, apical cells clavate, faintly constricted with obvious branch,

Fig. 35. Basidiomata of *Ganoderma sublobatum*.

dark brown, about 30–40 × 3–6 µm, forming an untidy palisade. *Cystidia* and *cystidioles* absent. *Basidia* barrel-shaped, colourless, thin-walled, 15–25 × 10–17 µm; *basidioles* clavate, colourless, thin-walled, 16–22 × 7–14 µm. *Basidiospores* ellipsoid, truncated, pale yellowish brown, IKI –, CB +, double-walled with distinctly thick walls, exospore wall smooth, endospore wall with dense spinules, (7.5–)9–11(–11.5) × (6–)6.5–8(–8.5) µm, L = 9.67 µm, W = 7.3 µm, Q = 1.32 (n = 30/1, with the turgid vesicular appendix excluded); (10.5–)11–12.5(–13) × 6.5–8.5(–9) µm, L = 11.41 µm, W = 7.25 µm, Q = 1.57 (n = 30/1, with the turgid vesicular appendix included).

Notes: *Ganoderma sublobatum* was collected from Queensland in Australia, it is closely related to *G. lobatum*. However, *G. lobatum* has perennial basidiomata with darker pilei, white pore surface, and smaller basidiospores (7–8.6 × 5–5.5 µm) which are different from *G. sublobatum*.

Ganoderma tongshanense B.K. Cui, J.H. Xing & Y.F. Sun, ***sp. nov.*** MycoBank MB 839683. Figs 37, 38.

Diagnosis: Differs from other species in the genus by its pale yellowish brown pileal surface, large pores, homogeneous context, non-stratified tubes, and ellipsoid and truncated basidiospores.

Etymology: *tongshanense* (*Lat.*), refers to the holotype of this species being found at Tongshan County of Hubei Province.

Typus: **China**, Hubei, Tongshan County, Jiugongshan National Park, on fallen trunk of angiosperm tree, 20 Oct. 2018, Cui 17168 (**holotype** BJFC030468).

Description: *Basidiomata* annual, sessile and broadly attached, hard corky. *Pilei* solitary, flabelliform, up to 7 cm diam and 2.5 cm thick. *Pileal* surface clay buff to pale yellowish brown, dull, glabrous, with concentric furrows and slightly radial wrinkles; margin obtuse, entire. *Pore surface* greyish white when fresh, turning darker when bruised, pale brown when dry; pores circular, shallow, 3–4 per mm; dissepiments moderately thick, entire. *Context* dark brown, homogeneous, without black melanoid lines, hard corky, up to 1.6 cm thick. *Tubes* slightly paler than context, non-stratified, stuffed with white mycelium, up to 9 mm long. *Hyphal system* trimitic; generative hyphae with clamp connections; all hyphae IKI –, CB +; tissues darkening in KOH. Generative hyphae in context colourless, thin-walled, 2–4 µm diam; skeletal hyphae in context dark brown, thick-walled with a wide to narrow lumen or sub-solid, arboriform and flexuous, 2–5 µm diam; binding hyphae in context colourless, thick-walled, branched and flexuous, up to 2 µm diam. Generative hyphae in tubes colourless, thin-walled, 2–4 µm diam; skeletal hyphae in tubes dark brown, thick-walled with a wide to narrow lumen or sub-solid, arboriform and flexuous, 2–5 µm diam; binding hyphae in tubes colourless, thick-walled, branched and flexuous, up to 2 µm diam. *Pileipellis* composed of clamped generative hyphae, thick-walled to sub-solid, apical cells clavate, inflated and

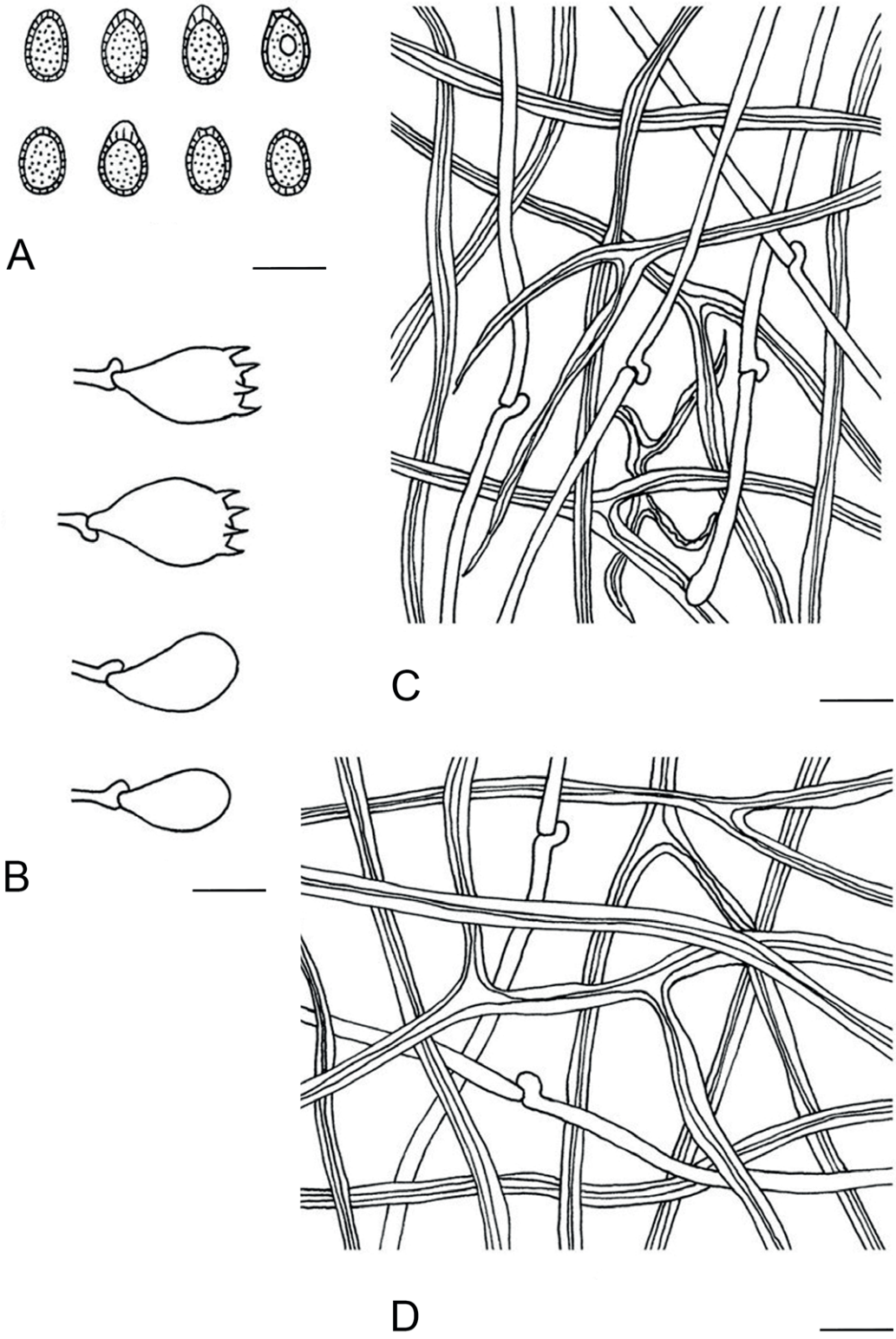

Fig. 36. Microscopic structures of *Ganoderma sublobatum* (drawn from Cui 16804). **A.** Basidiospores. **B.** Basidia and basidioles. **C.** Hyphae from trama. **D.** Hyphae from context. Scale bars = 10 µm.

flexuous, pale yellowish brown, about 30–45 × 6–8 µm, forming a regular palisade. *Cystidia* and *cystidioles* absent. *Basidia* clavate, colourless, thin-walled, 10–13 × 3–5 µm; *basidioles* in shape like the basidia, colourless, thin-walled, 8–11 × 4–6 µm. *Basidiospores* ellipsoid, truncated, pale yellowish brown, IKI –, CB +, double-walled with distinctly thick walls, exospore wall smooth, endospore wall with dense spinules, (8–)8.2–9.8(–10) × (5–)5.2–6.2(–6.5) µm, L = 8.91 µm, W = 5.62 µm, Q = 1.59 (n = 60/1, with the turgid vesicular appendix excluded); (9.2–)9.4–10.5(–11) × (5–)5.2–6.1(–6.3) µm, L = 9.81 µm, W = 5.65 µm, Q = 1.74 (n = 60/1, with the turgid vesicular appendix included).

Notes: Morphologically, *G. tongshanense* may be confused with *G. australe* which is widely distributed in South China. They share similar macro-morphological characters, but the latter has perennial and larger basidiomata and stratified tubes (Patouillard 1889, Ryvarden & Johansen 1980, Corner 1983). In the phylogenetic analyses, *G. tongshanense* and *G. australe* are distinct from each other (Fig. 1).

Fig. 37. Basidiomata of *Ganoderma tongshanense*.

Ganoderma yunlingense B.K. Cui, J.H. Xing & Y.F. Sun, ***sp. nov.*** MycoBank MB 839684. Figs 39, 40.

Diagnosis: Differs from other species in the genus by its non-laccate pileal surface with concentrically irregular ridges, extremely thin context, stratified tubes, and ovoid to almond-shaped basidiospores without spinules on the endospore wall.

Etymology: *yunlingense* (*Lat.*), refers to this species being collected from the Yunling Mountains of Yunnan Province.

Typus: **China**, Yunnan, Lanping County, Luoguqing, on fallen trunk of *Quercus*, 9 Sep. 2017, Cui 16288 (**holotype** BJFC029587).

Additional materials examined: **China**, Yunnan, Lijiang, Yulongxueshan, on stump of *Quercus*, 16 Sep. 2018, Cui 17043 (BJFC030342), Cui 17060 (BJFC030359); Lanping County, Luoguqing, on fallen trunk of *Quercus semecarpifolia*, 18 Sep. 2018, Cui 17161 (BJFC030461).

Description: *Basidiomata* perennial, sessile, hard corky to woody hard. *Pilei* solitary, flabelliform to shell-shaped, occasionally dimidiate, up to 11.5 cm diam and 10 cm thick. *Pileal surface* greyish brown to grey, dull, glabrous, with concentrically irregular ridges; margin acute, entire, wavy and sometimes lacerated as petals. *Pore surface* white when fresh, turning darker when bruised, straw yellow when dry; pores circular to angular, 4–6 per mm; dissepiments moderately thick, entire. *Context* extremely thin, without black melanoid lines. *Tubes* brown to dark brown, distinctly stratified, up to 5 cm long. *Hyphal system* trimitic; generative hyphae with clamp connections; all hyphae IKI –, CB +; tissues darkening in KOH. Generative hyphae in context colourless, thin-walled, 2–3.5 µm diam; skeletal hyphae in context yellowish brown, thick-walled with narrow lumen or sub-solid, arboriform and flexuous, 3–5.5 µm diam; binding hyphae in context colourless, thick-walled, branched and flexuous, 1.5–3 µm diam. Generative hyphae in tubes colourless, thin-walled, 2–3 µm diam; skeletal hyphae in tubes yellowish brown, thick-walled with narrow lumen or sub-solid, arboriform and flexuous, 2.5–5 µm diam; binding hyphae in tubes colourless, thick-walled, branched and flexuous, 1.5–3 µm diam. *Pileipellis* composed of clamped generative hyphae, thick-walled, apical cells clavate, flexuous, golden yellow to pale brown, about 25–40 × 4–7 µm, forming a regular palisade. *Cystidia* and *cystidioles* absent. *Basidia* barrel-shaped, colourless, thin-walled, 15–20 × 8–13 µm; *basidioles* clavate, colourless, thin-walled, 13–17 × 6–10 µm. *Basidiospores* ovoid to almond-shaped, not obviously truncated, pale yellowish brown, IKI –, CB +, double-walled with slightly thick walls, exospore wall smooth, endospore wall without spinules, (7.5–)8–10(–10.5) × (4.3–)4.8–5.5(–6) µm, L = 8.93 µm, W = 5.16 µm, Q = 1.70–1.73 (n = 60/2, with the turgid vesicular appendix excluded).

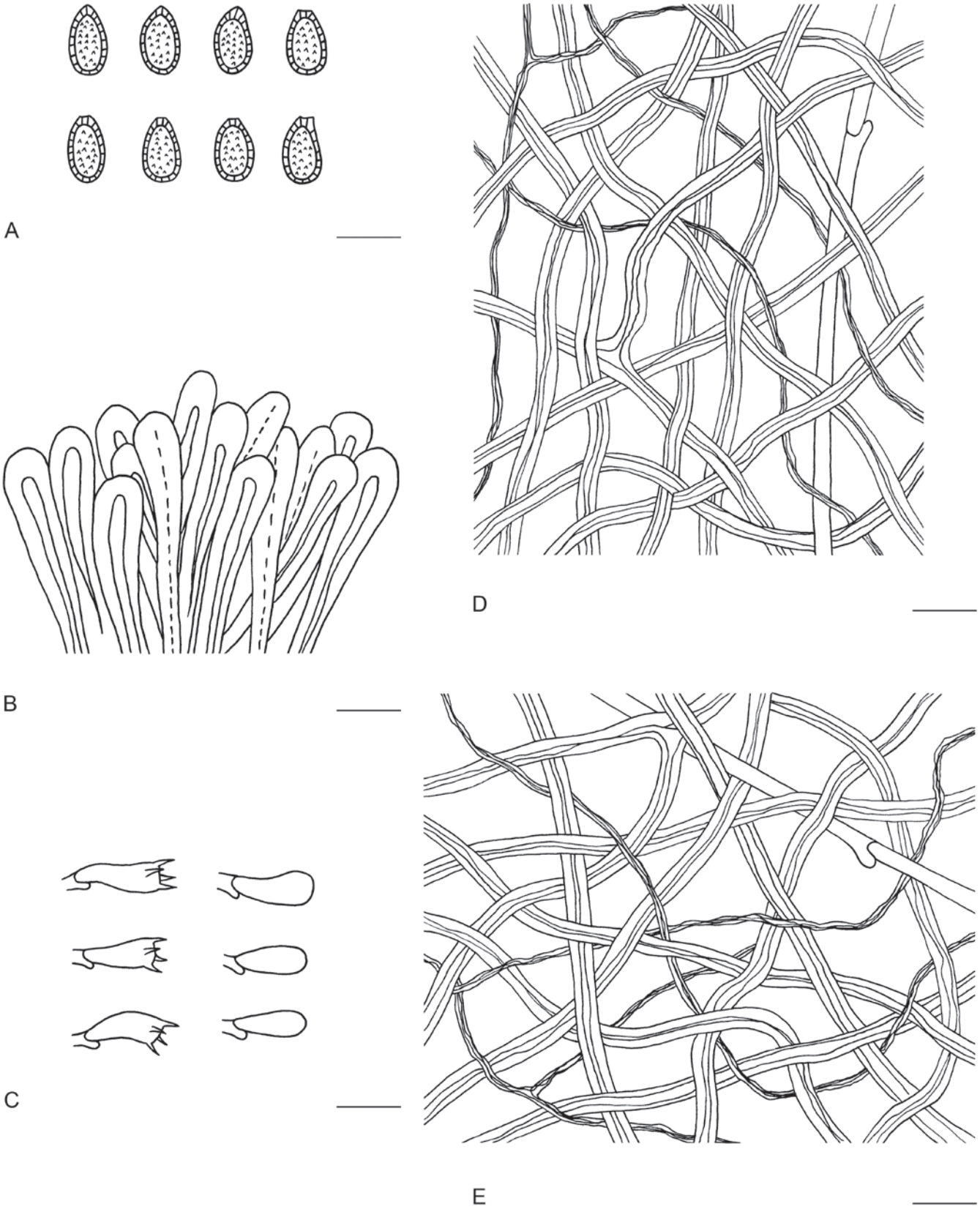

Fig. 38. Microscopic structures of *Ganoderma tongshanense* (drawn from Cui 17168). **A.** Basidiospores. **B.** Apical cells from cuticle. **C.** Basidia and basidioles. **D.** Hyphae from trama. **E.** Hyphae from context. Scale bars = 10 µm.

Notes: *Ganoderma yunlingense* is characterised by its non-laccate pileal surface with concentrically irregular ridges, extremely thin context, stratified and long tubes, basidiospores not obviously truncated, without spinules on the endospore wall. It may be confused with *G. acontextum* because of the dull pileal surface, thin context and basidiospores not obviously truncated without any ornamentation; however, *G. acontextum* was collected from the United States of America and has reddish brown pileal surface with dense concentric furrows, and non-stratified tubes.

Fig. 39. Basidiomata of *Ganoderma yunlingense*.

Notes on accepted species of *Ganoderma* recorded from China

Ganoderma ahmadii Steyaert, Persoonia 7: 91. 1972. MycoBank MB 314303.

For a detailed description of *Ganoderma ahmadii*, see Steyaert (1972) and Zhao (1989b).

Notes: *Ganoderma ahmadii* was described from Pakistan by Steyaert (1972). Zhao (1989b) examined an authentic specimen collected from Pakistan, but the description regarding the reddish brown pileal surface and homogeneous context is different to the original description. Wang (2005) studied one specimen of *G. ahmadii* collected from Sichuan Province in China and the ITS1-ITS2 sequences are similar to the records in GenBank. So, *G. ahmadii* was confirmed in Sichuan Province in China based on morphological and phylogenetic analyses.

Ganoderma angustisporum J.H. Xing *et al.*, MycoKeys 34: 98. 2018. MycoBank MB 823320.

For a detailed description of *Ganoderma angustisporum*, see Xing *et al.* (2018).

Notes: *Ganoderma angustisporum* was recently described from China and classified in *Ganoderma* according to its narrow and truncated basidiospores in *Ganoderma* (Xing *et al.* 2018). It is also found in Malaysia, Sri Lanka and Thailand.

Ganoderma applanatum (Pers.) Pat., Hyménomyc. Eur. (Paris): 143. 1887. MycoBank MB 119872. Figs 41, 42.
Basionym: *Boletus applanatus* Pers., Observ. Mycol. (Lipsiae) 2: 2. 1800.

Description: *Basidiomata* perennial, sessile and broadly attached, hard corky to woody hard. *Pilei* solitary or imbricate, variable, applanate, flabelliform to shell-like or ungulate, up to 23 cm diam and 7 cm thick. *Pileal surface* pale brown to dark brown, dull, glabrous, with shallow to deep concentric furrows; margin obtuse, entire and wavy. *Pore surface* white to pale brown when fresh, turning darker when bruised, greyish white to straw yellow when dry; pores circular to angular, 4–7 per mm; dissepiments moderately thick, mostly entire. *Context* yellowish brown to dark brown, homogeneous, with black melanoid lines when mature, corky, up to 3 cm thick. *Tubes* concolorous with context, stratified by a layer of context, up to 4 cm long. *Hyphal system* trimitic; generative hyphae with clamp connections; all hyphae IKI –, CB +; tissues darkening in KOH. Generative hyphae in context colourless, thin-walled, 2.5–7 µm diam; skeletal hyphae in context pale yellowish brown, thick-walled with a wide to narrow lumen or sub-solid, frequently arboriform and flexuous, 3.5–6.5 µm diam; binding hyphae in context colourless, thick-walled, branched and flexuous, 2–3 µm diam. Generative hyphae in tubes colourless, thin-walled, 2–3.5 µm diam; skeletal hyphae in tubes pale brown to dark brown, thick-walled with a wide to narrow lumen or sub-solid, frequently arboriform and flexuous, 2–4.5 µm diam; binding hyphae in tubes colourless, thick-walled, branched and flexuous, 1–2.5 µm diam. *Cystidia*, *cystidioles*, *basidia* and *basidioles*

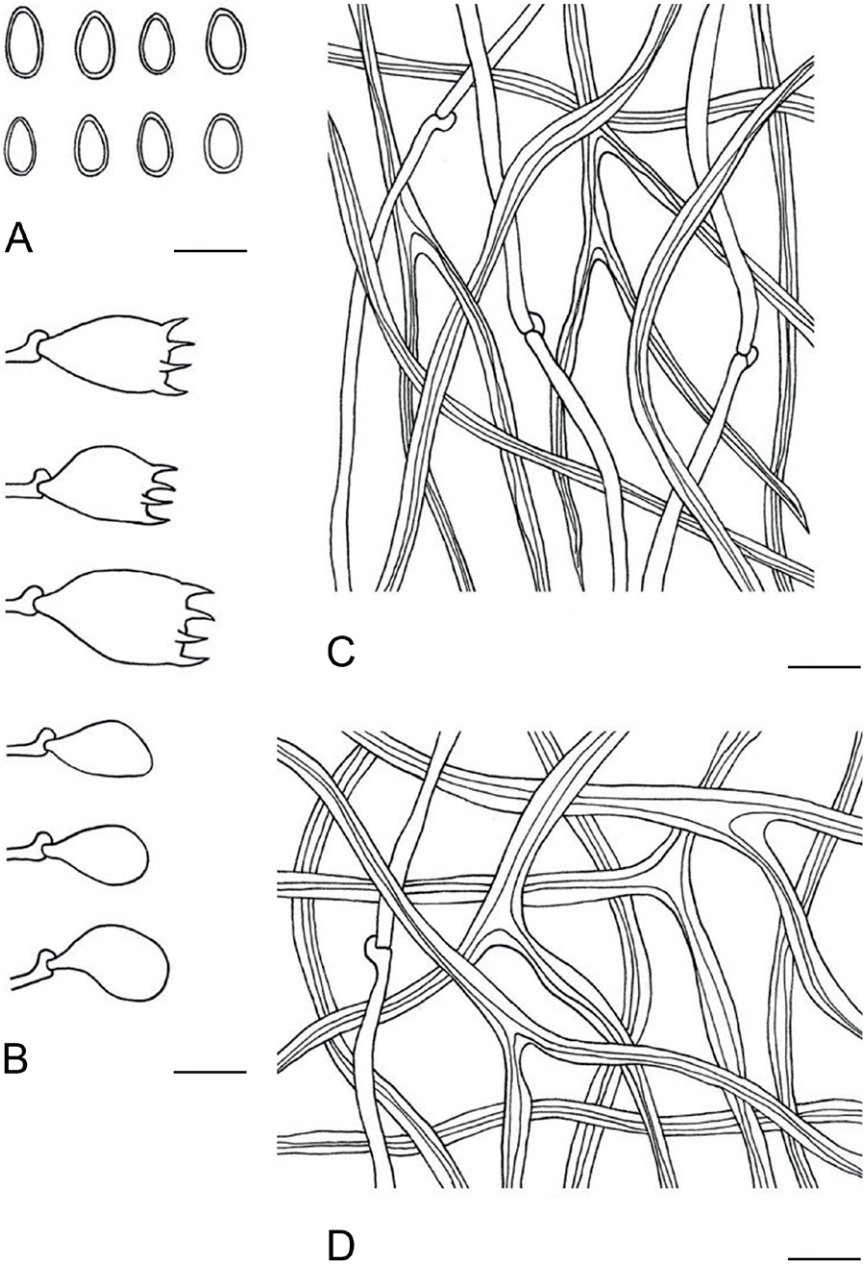

Fig. 40. Microscopic structures of *Ganoderma yunlingense* (drawn from Cui 16288). **A.** Basidiospores. **B.** Basidia and basidioles. **C.** Hyphae from trama. **D.** Hyphae from context. Scale bars = 10 µm.

absent. *Basidiospores* ellipsoid, truncated, yellowish to pale brown, IKI –, CB +, double-walled with moderately thick walls, exospore wall smooth, endospore wall with dense spinules, (5–)5.5–7(–8) × (4–)4.1–5.2(–6) µm, L = 6.25 µm, W = 4.56 µm, Q = 1.37 (n=30/1, with the turgid vesicular appendix included).

Additional materials examined: **China**, Jilin, Jiaohe, Hongyegu Park, on stump of angiosperm tree, 1 Aug. 2016, Cui 14062 (BJFC028930); on stump of *Betula*, 1 Aug. 2016, Cui 14070 (BJFC028938); Fusong County, Changbaishan Nature Reserve, on fallen trunk of angiosperm tree, 3 Aug. 2016, Cui 14121 (BJFC028989).

Notes: *Ganoderma applanatum* was firstly described from Europe and has a Holarctic distribution (Steyaert 1972, Moncalvo & Ryvarden 1997, Hapuarachchi *et al.* 2019b). *Ganoderma applanatum* is similar with *G. australe* based on perennial and sessile basidiomata, non-laccate and pale pileal surface, brown to dark brown context, but the latter has larger basidiospores (7–12 × 5–8 µm, Ryvarden 2004b). Besides, *G. applanatum* and *G. australe* can be separated in the phylogenetic analyses (Fig. 1).

Ganoderma australe (Fr.) Pat., Bull. Soc. Mycol. Fr. 5: 65. 1889. MycoBank MB 100745.
Basionym: *Polyporus australis* Fr., Elench. Fung. (Greifswald) 1: 108. 1828.
Synonyms: *Ganoderma triangulum* J.D. Zhao & L.W. Hsu, Acta Mycol. Sin. 3: 18. 1984.
Ganoderma ungulatum J.D. Zhao & X.Q. Zhang, Acta Mycol. Sin. 3: 19. 1984.
Ganoderma bawanglingense J.D. Zhao & X.Q. Zhang, Acta Mycol. Sin. 6: 205. 1987.
Ganoderma mirivelutinum J.D. Zhao, Acta Mycol. Sin. 7: 206. 1987.

For a detailed description of *G. australe*, see Ryvarden (2004b) and Hapuarachchi *et al.* (2018b).

Fig. 41. Basidiomata of *Ganoderma applanatum*.

Notes: *Ganoderma australe* was described from an island in the Pacific Ocean, but the type specimen has been lost and the only specimen deposited at the Royal Botanic Gardens Kew was from Europe which is inconsistent with its tropical distribution (Moncalvo & Ryvarden 1997). Cao (2013) suggested that *G. bawanglingense*, *G. mirivelutinum*, *G. triangulum* and *G. ungulatum* should be regarded as the synonyms of *G. applanatum*, but their tropical distribution and morphological similarity of *G. australe* support that they should be treated as the synonyms of *G. australe*. *Ganoderma australe* may be confused with *G. adspersum*, *G. applanatum* and *G. gibbosum* in morphology. Previously, many specimens collected from South China were identified as "*Ganoderma australe*". Two specimens from Australia are recognised as *G. australe* by Costa-Rezende *et al.* (2017), and most specimens collected from South China clustered with *G. gibbosum* (Fig. 1). Whether there is true *G. australe* in China is unknown and more detailed studies about the *G. australe* complex should be done.

Ganoderma boninense Pat., Bull. Soc. Mycol. Fr. 5: 72. 1889. MycoBank MB 100062.

For a detailed description of *G. boninense*, see Steyaert (1967) and Ryvarden (1983).

Notes: *Ganoderma boninense* was described from the Bonin Islands in Japan, and it has been recognised as the main pathogen of oil palm trees causing a basal stem rot (Pilotti 2005). *Ganoderma boninense* can be distinguished by its reddish and shiny pileal surface, irregular apical cells with swellings and protuberance of pileipellis, and oblong ellipsoid basidiospores (Ryvarden 1983). Cao (2013) compared the specimens collected from Hainan Province and Japan, and they showed very similar morphological characters and ITS sequences.

Ganoderma calidophilum J.D. Zhao *et al.*, Acta Microbiol. Sin. 19: 270. 1979. MycoBank MB 314307.

For a detailed description of *G. calidophilum*, see Zhao *et al.* (1979) and Luangharn *et al.* (2021).

Notes: Zhao *et al.* (1979) described *Ganoderma calidophilum* from Hainan Province based on its small basidiomata with heterogenous context, whitish pore surface and large basidiospores (10–12.1 × 6.2–8.7 µm). The sequences of *G. calidophilum* used in this study were downloaded from GenBank, and showed to be distinct from *G. flexipes* (Fig. 1), which has been considered as a doubtful synonym (Wang & Wu 2014).

Ganoderma casuarinicola J.H. Xing *et al.*, MycoKeys 34: 100. 2018. MycoBank MB 823321.

For a detailed description of *G. casuarinicola*, see Xing *et al.* (2018) and Luangharn *et al.* (2019).

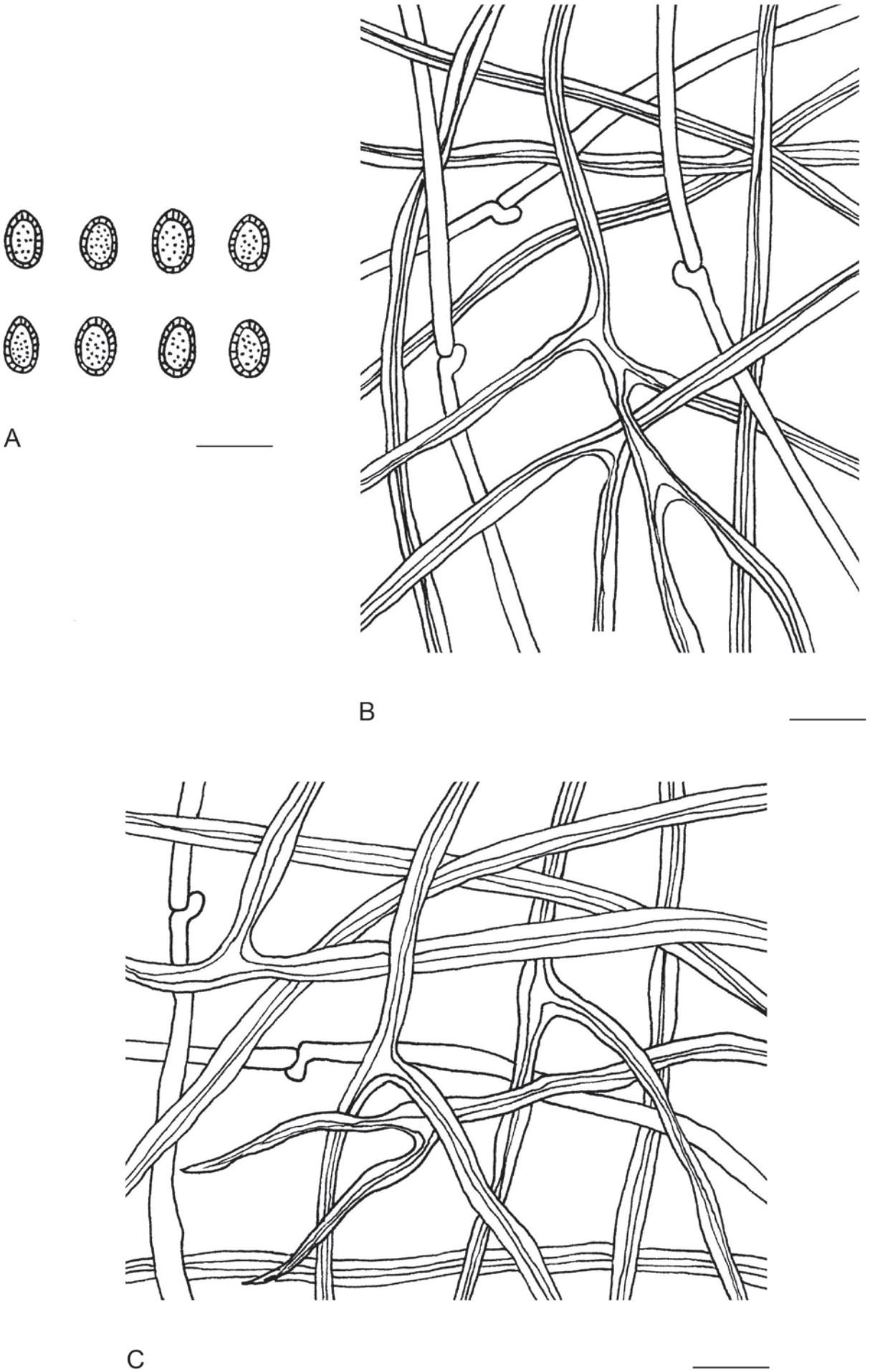

Fig. 42. Microscopic structures of *Ganoderma applanatum* (drawn from He 2139). **A.** Basidiospores. **B.** Hyphae from trama. **C.** Hyphae from context. Scale bars = 10 µm.

Notes: *Ganoderma casuarinicola* was collected on a living tree of *Casuarina equisetifolia* from Guangdong Province in China by Xing *et al.* (2018). Luangharn *et al.* (2019) reported *G. casuarinicola*, where it was found on *Pinus kesiya* stump, as a new record from Thailand. There are some differences such as applanate to dimidiate pilei, longer tubes and larger basidiospores when comparing these specimens with the type of *G. casuarinicola* (Dai 16336). Geographical and climatic divergences may be the reason for the intraspecific differences (Boddy *et al.* 2014).

Ganoderma ellipsoideum Hapuar. *et al.*, Mycosphere 9: 951. 2018. MycoBank MB 554384.

For a detailed description of *G. ellipsoideum*, see Hapuarachchi *et al.* (2018b).

Notes: *Ganoderma ellipsoideum* is distinguished by its ellipsoid spores (6.1–7.3 × 3.7–4.6 µm) with distinct spinules on the endospore wall. Hapuarachchi *et al.* (2018b) stated that *G. ellipsoideum* was known only from the type locality of Hainan Province in China. In this study, several specimens collected from Yunnan and Guangdong provinces showed similar morphological features and close phylogenetic relationships with *G. ellipsoideum*.

Ganoderma flexipes Pat., Bull. Soc. Mycol. Fr. 23: 75. 1907. MycoBank MB 249905. Figs 43, 44.
Synonyms: *Ganoderma atrum* J.D. Zhao *et al.*, Acta Microbiol. Sin. 19: 268. 1979.
Ganoderma hainanense J.D. Zhao *et al.*, Acta Microbiol. Sin. 19: 269. 1979.
Ganoderma parviungulatum J.D. Zhao & X.Q. Zhang, Acta Mycol. Sin. 5: 88. 1986.

Description: *Basidiomata* annual, dorso-laterally stipitate, hard corky to woody hard. *Pilei* solitary, variable, flabelliform to shell-like or circular, up to 5 cm diam and 1.5 cm thick. *Pileal surface* dark brown to reddish brown, strongly laccate, glabrous, with obvious concentric furrows and slightly radial rugose; margin obtuse, entire, slightly incurved. *Pore surface* white when fresh, turning darker when bruised, light buff when dry; pores circular to angular, 4–6 per mm; dissepiments slightly thick, entire. *Context* heterogeneous, the upper layer pale yellowish brown, the lower layer dark brown, with black melanoid lines, corky, up to 3 mm thick. *Tubes* dark brown, non-stratified, up to 1.2 cm long. *Stipe* reddish brown to purplish black, flattened to cylindrical, up to 25 cm long and 6 mm diam. *Hyphal system* trimitic; generative hyphae with clamp connections; all hyphae IKI –, CB +; tissues darkening in KOH. Generative hyphae in context colourless, thin-walled, 1.5–3.5 µm diam; skeletal hyphae in context pale yellowish brown, thick-walled with a narrow lumen or sub-solid, arboriform and flexuous, 2.5–6 µm diam; binding hyphae in context colourless, thick-walled, branched and flexuous, 1–2 µm diam. Generative hyphae in tubes colourless, thin-walled, occasionally branched, 2–3 µm diam; skeletal hyphae in tubes pale brown to dark brown, thick-walled with a narrow lumen to sub-solid, frequently arboriform and flexuous, 2–4 µm diam; binding hyphae in tubes colourless, thick-walled, branched and flexuous, 0.5–1 µm diam. *Pileipellis* composed of clamped generative hyphae, thick-walled to sub-solid, apical cells clavate, slightly inflated, pale brown to yellowish brown, 30–45 × 5–10 µm, forming a regular palisade. *Cystidia* and *cystidioles* absent. *Basidia* barrel-shaped, colourless, thin-walled, 23–30 × 12–17 µm; *basidioles* in shape like the basidia, colourless, thin-walled, 17–23 × 8–13 µm. *Basidiospores* ellipsoid, not obviously truncated, pale yellowish brown, IKI –, CB +, double-walled with moderately thick walls, exospore wall smooth, endospore walls with dense spinules, (6.5–)7–9(–9.5) × (4–)4.8–5.5(–6) µm, L = 8.17 µm, W = 5.23 µm, Q = 1.56 (n = 30/1, with the turgid vesicular appendix excluded).

Materials examined: **China**, Guangdong, Guangzhou, campus of Sun Yat-Sen University, on stump of angiosperm tree, 20 Jul. 2012, Cui 17209 (BJFC030563); Hainan, Qiongzhong County, Limushan Forest Park, on ground of angiosperm forest, 16 Jun. 2016, Cui 13841 (BJFC028707); Changjiang County, Bawangling Nature Reserve, on ground of angiosperm forest, 18 Jun. 2016, Cui 13863 (BJFC028729); Yunnan, Puer, Puer Forest Park, on rotten angiosperm wood, 17 Aug. 2019, Dai 20461 (BJFC032129).

Notes: *Ganoderma flexipes* was first described from Vietnam by Patouillard (1907), and many researchers have conducted detailed studies on it (Steyaert 1972, Ryvarden 1983, Hapuarachchi *et al.* 2019b). Cao (2013) considered *G. atrum*, *G. hainanense*

Fig. 43. Basidiomata of *Ganoderma flexipes*.

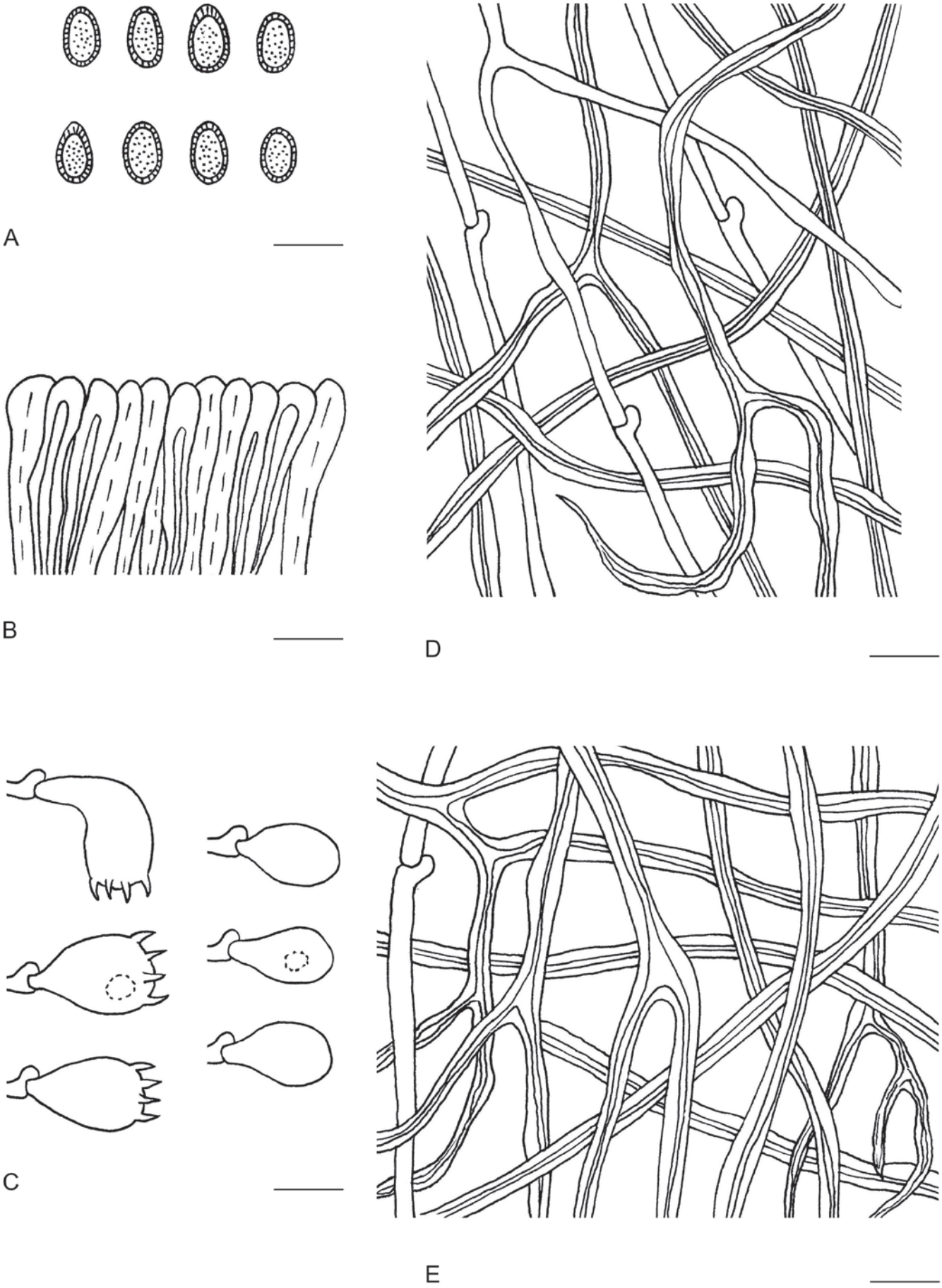

Fig. 44. Microscopic structures of *Ganoderma flexipes* (drawn from Cui 13882). **A.** Basidiospores. **B.** Apical cells from cuticle. **C.** Basidia and basidioles. **D.** Hyphae from trama. **E.** Hyphae from context. Scale bars = 10 µm.

and *G. parviungulatum* as synonyms of *G. flexipes* based on comprehensive observations of the holotype specimens.

Ganoderma gibbosum (Blume & T. Nees) Pat., Ann. Jard. Bot. Buitenzorg, suppl. 1: 114. 1897. MycoBank MB 250058.
Basionym: *Polyporus gibbosus* Blume & T. Nees, Nova Acta Phys.-Med. Acad. Caes. Leop.-Carol. Nat. Cur. 13: 19. 1826.

For a detailed description of *G. gibbosum*, see Luangharn *et al.* (2020).

Notes: *Ganoderma gibbosum* was first described from Java, however, the type specimen was lost (Moncalvo & Ryvarden, 1997). In previous studies, *G. gibbosum* was regarded as a synonym of *G. applanatum* or classified in the *G. applanatum–australe* complex based on the non-laccate basidiomata (Zhao 1989b, Moncalvo & Ryvarden 1997). Luangharn *et al.* (2020) conducted a study on the taxonomy of *G. gibbosum* collected from Kunming, China, and the results showed that samples of *G. gibbosum* from Asia and South America formed two different lineages. In this study, specimens of *G. gibbosum* collected from Guangdong, Guangxi and Sichuan provinces clustered together and formed a well-supported lineage (Fig. 1).

Ganoderma hoehnelianum Bres., Annls Mycol. 10: 502. 1912. MycoBank MB 243431. Figs 45, 46.
Synonym: *Ganoderma shangsiense* J.D. Zhao, Acta Mycol. Sin. 7: 17. 1988.

Description: *Basidiomata* perennial, sessile or broadly attached to laterally stipitate, hard corky to woody hard. *Pilei* solitary, variable, flabelliform or shell-like to reniform, applanate, up to 10 cm diam and 2.2 cm thick. *Pileal surface* yellowish brown to dark brown, dull, glabrous, with obvious concentric furrows; margin acute to obtuse, entire. *Pore surface* white when fresh, turning darker when bruised, straw yellow to pale yellowish brown when dry; pores circular to angular, 3–6 per mm; dissepiments moderately thick, entire. *Context* heterogeneous, the upper layer pale yellowish brown, the lower layer dark brown, with black melanoid lines, corky, up to 1 cm thick. *Tubes* light buff to greyish brown, stratified, up to 1.2 cm long. *Stipe* dark brown, flattened, up to 3 cm long and 6 mm diam. *Hyphal system* trimitic; generative hyphae with clamp connections; all hyphae IKI –, CB +; tissues darkening in KOH. Generative hyphae in context absent; skeletal hyphae in context pale yellowish brown, thick-walled with a wide to narrow lumen or sub-solid, frequently arboriform and flexuous, 2–4 µm diam; binding hyphae in context colourless, thick-walled, branched and flexuous, 1–2.5 µm diam. Generative hyphae in tubes colourless, thin-walled, 2.3–3.5 µm diam; skeletal hyphae in tubes pale brown to dark brown, thick-walled with a narrow lumen or sub-solid, frequently arboriform and flexuous, 2–5 µm diam; binding hyphae in tubes colourless, thick-walled, branched and flexuous, 1.5–3 µm diam. *Cystidia* and *cystidioles* absent. *Basidia* absent; *basidioles* barrel-shaped, colourless, thin-walled, 21–30 ×9–13 µm. *Basidiospores* subglobose, not obviously truncated, pale yellowish brown, IKI –, CB +, double-walled with distinctly thick walls, exospore walls smooth, endospore walls with dense spinules, (6.5–)7–8.2(–9) × (–5.5)5.8–7.8(–8) µm, L = 7.43 µm, W = 6.73 µm, Q = 1.1 (n = 30/1).

Fig. 45. Basidiomata of *Ganoderma hoehnelianum*.

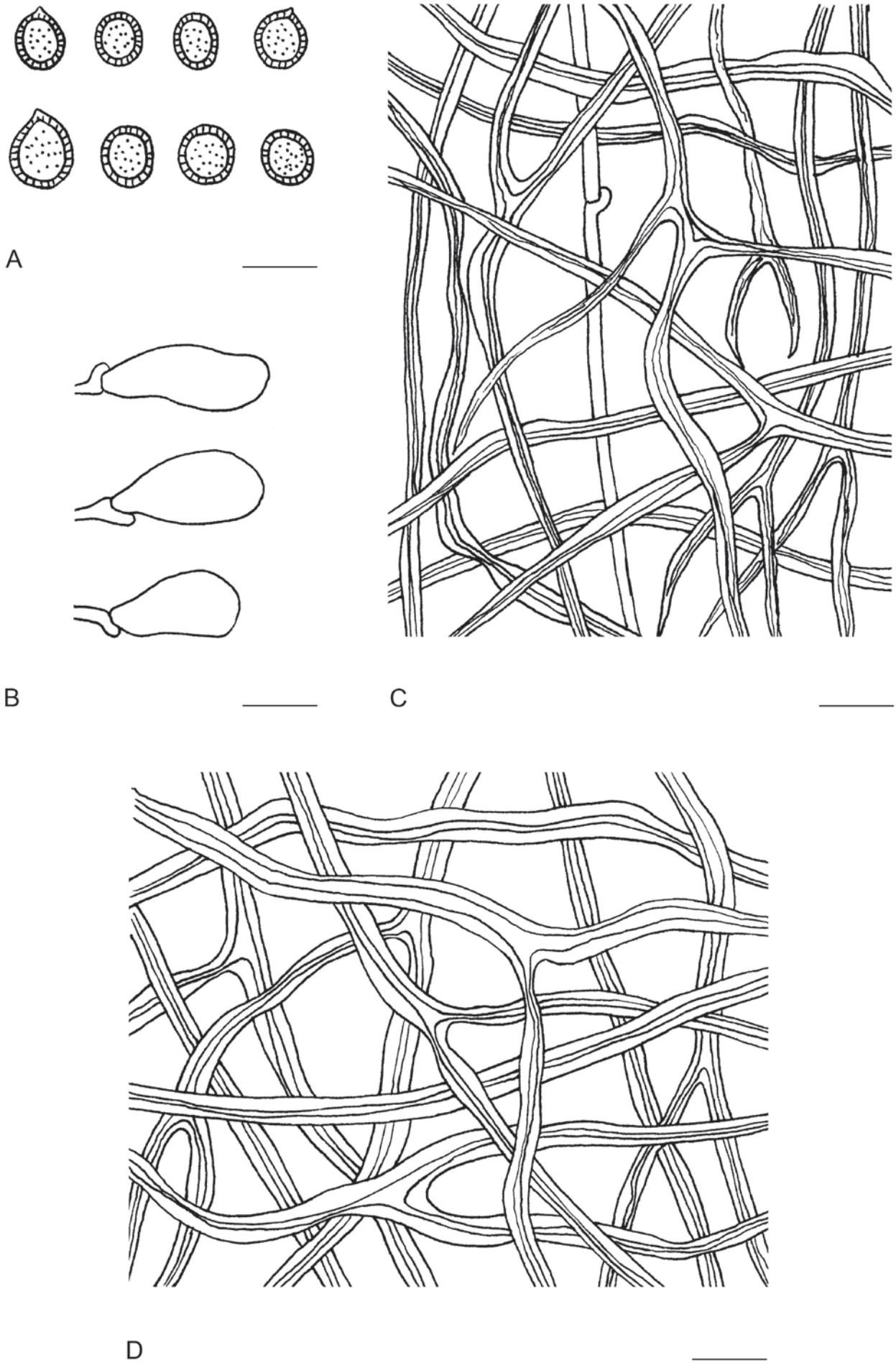

Fig. 46. Microscopic structures of *Ganoderma hoehnelianum* (drawn from Dai 16166). **A.** Basidiospores. **B.** Basidioles. **C.** Hyphae from trama. **D.** Hyphae from context. Scale bars = 10 µm.

Materials examined: **China**, Hainan, Ledong County, Jianfengling Nature Reserve, on stump of angiosperm tree, 19 Jun. 2016, Cui 13904 (BJFC028770); Guangxi, Shangsi County, Shiwandashan Forest Park, on dead tree of angiosperm, 6 Jul. 2016, Cui 13982 (BJFC028850); Nanning, Guangxi Academy of Forestry, on living tree of angiosperm, 21 Aug. 2019, Dai 20783 (BJFC032450); Yunnan, Mengla County, Wangtianshu Park, 20 Jul. 2014, Dai 13915 (BJFC017645).

Notes: *Ganoderma hoehnelianum* was described by Bresadola from Java. It has typically ganodermoid macro-morphological features, but the obviously amaurodermoid basidiospores make *G. hoehnelianum* different from other species. In the phylogenetic analyses, *G. hoehnelianum* grouped in the *Ganoderma* clade, and formed an independent lineage with high support (Fig. 1). Wang & Wu (2010) and Cao (2013) regarded *G. shangsiense* as a synonym of *G. hoehnelianum* after the studies on the holotype of *G. shangsiense*.

Ganoderma leucocontextum T.H. Li *et al.*, Mycoscience 56: 82. 2015. MycoBank MB 804187.

For a detailed description of *G. leucocontextum*, see Li *et al.* (2015).

Notes: *Ganoderma leucocontextum* as a member of the *G. lucidum* complex shares reddish brown and laccate pilei and truncated basidiospores, but it is distinguished by the white context Li *et al.* (2015). In the current study, *G. leucocontextum* grouped with *G. weixiense* (Fig. 1). According to the comparison between *G. leucocontextum* and *G. weixiense* in Ye *et al.* (2019), the size of pores (4–6 per mm *vs* 2–4 per mm) and basidiospores (9.5–12.5 × 7–9 µm *vs* 6–8 × 3–4 µm) are the main differences.

Ganoderma lingzhi Sheng H. Wu *et al.*, Fungal Divers. 56: 54. 2012. MycoBank MB 564240.

For a detailed description of *G. lingzhi*, see Cao *et al.* (2012).

Notes: Cao *et al.* (2012) revised the taxonomic status of the widely cultivated "*Ganoderma lucidum*" in China and described it as a new species called *G. lingzhi* based on geographical distribution, morphological features and phylogenetic analyses. *Ganoderma lingzhi* is widely distributed in temperate and subtropical areas of China, and it has also been reported from Korea and Laos (Kim *et al.* 2001, Hapuarachchi *et al.* 2019b).

Ganoderma lucidum (Curtis) P. Karst., Revue Mycol., Toulouse 3: 17. 1881. MycoBank MB 148413. Figs 47, 48.
Basionym: *Boletus lucidus* Curtis, Fl. Londin. 1: 72. 1781.
Synonym: *Ganoderma cantharelloideum* M.H. Liu, Acta Mycol. Sin. 8: 279. 1989.

Description: *Basidiomata* annual, laterally stipitate, hard corky to woody hard. *Pilei* solitary, variable, flabelliform or shell-like to circular, up to 11 cm diam and 3 cm thick. *Pileal surface* yellowish brown to reddish brown, laccate, glabrous, with concentric furrows; margin acute to obtuse, entire, slightly wavy. *Pore surface* white when fresh, turning darker when bruised, pale yellow to straw yellow when dry; pores circular, 4–6 per mm; dissepiments slightly thick, mostly entire. *Context* heterogeneous, the upper layer cream to buff, the lower layer clay-buff, without black melanoid lines, soft corky, up to 1.8 cm thick. *Tubes* pale brown, non-stratified, up to 1.2 cm long. *Stipe* reddish brown to purplish black, flattened to cylindrical, up to 12 cm long and 1.5 cm diam. *Hyphal system* trimitic; generative hyphae with clamp connections; all hyphae IKI –, CB +; tissues darkening in KOH. Generative hyphae in context colourless, thin-walled, 2.5–4 µm diam; skeletal hyphae in context pale yellowish brown, thick-walled with a narrow lumen or sub-solid, frequently arboriform and flexuous, 3–10 µm diam; binding hyphae in context colourless, thick-walled, branched and flexuous, 2–3 µm diam. Generative hyphae in tubes colourless, thin-walled, 2–3 µm diam; skeletal hyphae in tubes pale brown to dark brown, thick-walled with a narrow lumen or sub-solid, frequently arboriform and flexuous, 2–8 µm diam; binding hyphae in tubes colourless, thick-walled, branched and flexuous, 1–2.5 µm diam. *Pileipellis* composed of clamped generative hyphae, thick-walled to sub-solid, apical cells clavate, strongly inflated and flexuous, pale yellowish brown, about 30–50 × 8–16 µm, forming a regular palisade. *Cystidia* and *cystidioles* absent. *Basidia* absent; *basidioles* barrel-shaped, colourless, thin-walled, 20–25 ×9–12 µm. *Basidiospores* ellipsoid, truncated, pale yellowish brown, IKI –, CB +, double-walled with moderately to distinctly thick walls, exospore walls smooth, endospore walls with dense spinules, (7–)7.5–9.5(–10) × (5–)5.5–7(–7.5) µm, L = 8.52 µm, W = 6.2 µm, Q = 1.37 (n = 30/1, with the turgid vesicular appendix excluded); (8–)9–11(–11.5) × (5–)5.5–7(–8) µm, L = 10.05 µm, W = 6.45 µm, Q = 1.56 (n = 30/1, with the turgid vesicular appendix included).

Materials examined: **China**, Sichuan, Qingchuan County, Qingxi Town, on stump of *Quercus*, 31 Oct. 2016, Cui 14404 (BJFC029272), Cui 14405 (BJFC029273), Cui 14406 (BJFC029274); Yunnan, Kunming, Xiaoshao Forest Farm, on rotten angiosperm wood, 1 Jul. 2019, Dai 20017 (BJFC031691).

Notes: *Ganoderma lucidum* was firstly described from London in the UK. It is the type species of *Ganoderma* and has the typical ganodermoid characters, such as stipitate basidiomata with laccate pileal surface, and truncated basidiospores with spinules on the endospore walls (Steyaert 1972, Ryvarden 2004b). Cao (2013) suggested that *G. cantharelloideum* should be treated as a synonym of *G. lucidum* according to the original description and observations on the holotype of *G. cantharelloideum*. In the current phylogenetic study, the *G. lucidum* lineage consisted of specimens collected from the UK, Czech Republic and China with high divergence (Figs 1, 2). The divergence in *G. lucidum* groups also appeared in phylogenetic analyses inferred from single or multiple genes by Zhou *et al.* (2015), Hapuarachchi *et al.* (2018b), Liu *et al.* (2019) and Luangharn *et al.* (2021). This may be caused by geographic separation. An essential systemic study of the *G. lucidum* lineage should be conducted based on more specimens from different regions and more gene markers.

Ganoderma magniporum J.D. Zhao & X.Q. Zhang, Acta Mycol. Sin. 3: 15. 1984. MycoBank MB 124473.

For a detailed description of *G.a magniporum*, see Zhao *et al.* (1984).

Notes: *Ganoderma magniporum* was described from Guangxi of South China based on its small and nearly black pilei, large pores (2–2.5 per mm), and ellipsoid basidiospores (8.7–10.4 × 5.2–7 µm, Zhao *et al.* 1984). Cao (2013) observed the type specimen (HMAS 42696) of *G. magniporum*, and stated it was immature and had smaller basidiospores than another specimen (Zhou 439) collected from Guangxi. In the current study, one specimen collected from Yunnan grouped with *G. magniporum*.

Fig. 47. Basidiomata of *Ganoderma lucidum*.

Ganoderma multipileum Ding Hou, Quarterly Journal of the Taiwan Museum 3: 101. 1950. MycoBank MB 344109.
Synonym: *Ganoderma chenghaiense* J.D. Zhao, Acta Mycol. Sin. 8: 31. 1989.

For a detailed description of *Ganoderma multipileum*, see Wang *et al.* (2009).

Notes: *Ganoderma multipileum* was described from Taiwan (China) based on its imbricate basidiomata with yellowish brown to reddish brown pileal surface, small pores (6–8 per mm), corky context, and ellipsoid to ovoid basidiospores (Wang *et al.* 2009). Cao (2013) studied the holotype of *G. multipileum* and *G. chenghaiense*, and suggested that the latter should be a synonym of *G. multipileum* based on the morphological characters. As more specimens were collected, the distribution of *G. multipileum* became widespread, found in South China, Laos and India. In the phylogenetic analysis, one specimen collected from the type locality was included and *G. multipileum* formed a stable lineage with good support (Fig. 1).

Ganoderma mutabile Y. Cao & H.S. Yuan, Mycol. Prog. 12: 122. 2013. MycoBank MB 563047. Figs 49, 50.

Description: *Basidiomata* perennial, sessile, hard corky to woody hard. *Pilei* solitary, flabelliform to shell-like, up to 18 cm diam and 7 cm thick. *Pileal surface* reddish brown to purplish brown, laccate, glabrous, with concentric furrows; margin obtuse, entire, slightly wavy. *Pore surface* white when fresh, turning darker when bruised, dark brown when dry; pores circular to angular, 4–5 per mm; dissepiments moderately thick, entire. *Context* brown, homogeneous, with black melanoid lines, hard corky, up to 3 cm thick. *Tubes* brown, stratified, up to 4 cm long. *Hyphal system* trimitic; generative hyphae with clamp connections; all hyphae IKI –, CB +; tissues darkening in KOH. Generative hyphae in context colourless, thin-walled, 2–3.5 µm diam; skeletal hyphae in context pale brown, thick-walled with a narrow lumen or sub-solid, frequently arboriform and flexuous, 2–5.5 µm diam; binding hyphae in context colourless, thick-walled, branched and flexuous, 1–2.5 µm diam. Generative hyphae in tubes colourless, thin-walled, 2–3 µm diam; skeletal hyphae in tubes pale brown, thick-walled with a narrow lumen or sub-solid, frequently arboriform and flexuous, 2–4.5 µm diam; binding hyphae in tubes colourless, thick-walled, branched and flexuous, 1–2.5 µm diam. *Pileipellis* composed of clamped generative hyphae, thick-walled to sub-solid, apical cells mostly with lateral outgrowths and protuberances, branched and flexuous, yellowish brown, about 40–65 × 4–9 µm, forming an irregular palisade. *Cystidia*, *cystidioles*, *basidia* and *basidioles* absent. *Basidiospores* broadly ellipsoid, truncated, pale yellowish brown, IKI –, CB +, double-walled with distinctly thick walls, exospore walls smooth, endospore walls with dense spinules, (7.5–)8–11(–11.5) × 5.5–7(–7.5) µm, L = 9.1 µm, W = 6.25 µm, Q = 1.46 (n = 30/1, with the turgid vesicular appendix excluded); (8.5–)9–12.5(–13) × (5.5–)6–7.5(–8) µm, L = 10.57 µm, W = 6.83 µm, Q = 1.55 (n = 30/1, with the turgid vesicular appendix included).

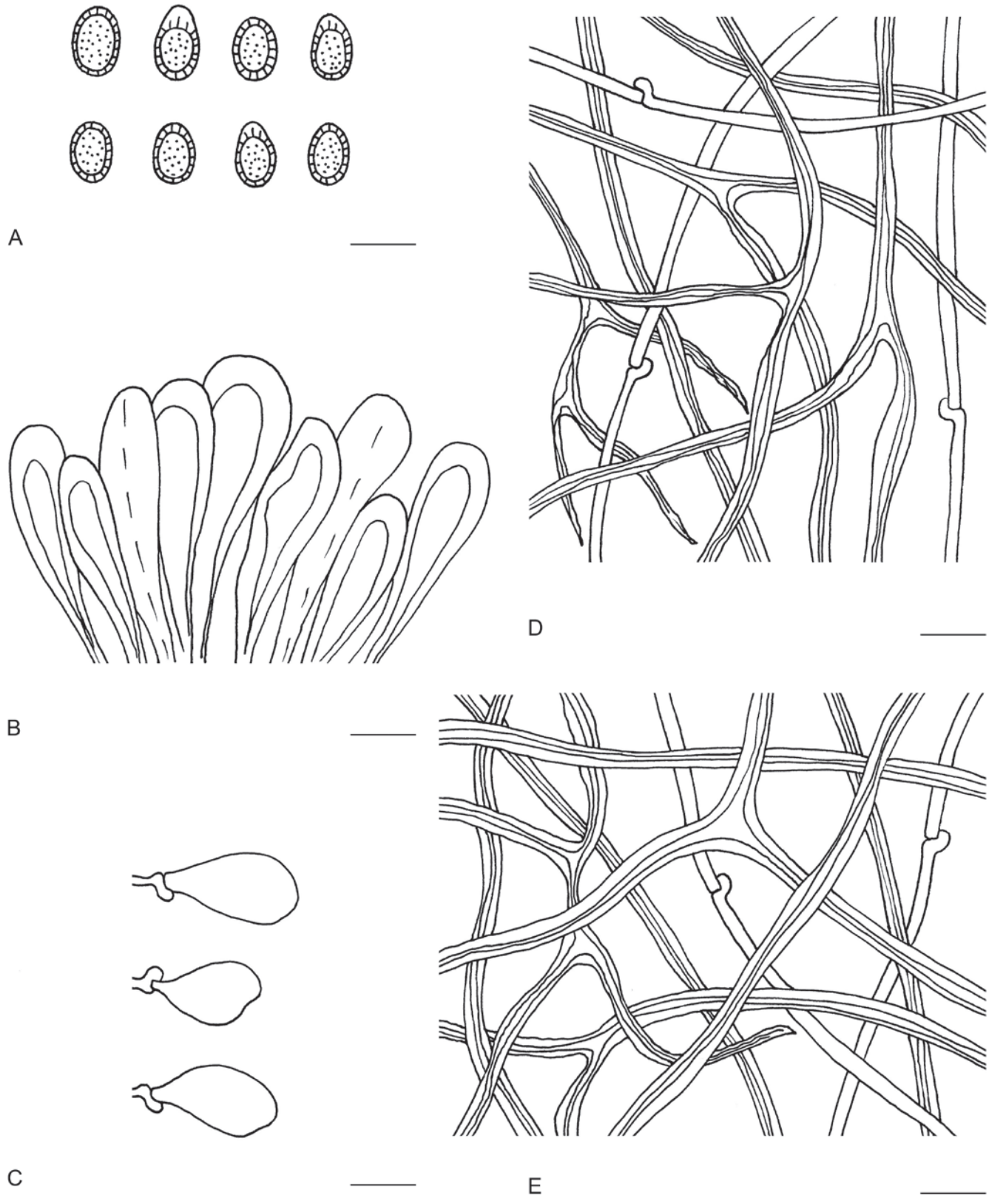

Fig. 48. Microscopic structures of *Ganoderma lucidum* (drawn from Dai 15805). **A.** Basidiospores. **B.** Apical cells from cuticle. **C.** Basidioles. **D.** Hyphae from trama. **E.** Hyphae from context. Scale bars = 10 μm.

Materials examined: **China**, Yunnan, Chuxiong, Zixishan Forest Park, on living tree of angiosperm, 8 Sep. 2006, **holotype** Yuan 2289 (IFP); Xinping County, Mopanshan Forest Park, on ground of mixed forest, 16 Aug. 2019, Dai 20414 (BJFC032082); Xizang, on angiosperm wood, Dec. 2018, Cui 17189 (BJFC030489).

Notes: *Ganoderma mutabile* was described from Yunnan in China based on the irregular apical cells of the pileipellis which are strongly flexuous and frequently branched Cao & Yuan (2012). Only one specimen was included in the original description, and in this study additional specimens were collected from Yunnan and Xizang.

Fig. 49. Basidiomata of *Ganoderma mutabile*.

Ganoderma orbiforme (Fr.) Ryvarden, Mycologia 92: 187. 2000. MycoBank MB 464692.
Basionym: *Polyporus orbiformis* Fr., Epicr. Syst. Mycol. (Upsaliae): 463. 1838.
Synonyms: *Ganoderma fornicatum* (Fr.) Pat., Bull. Soc. Mycol. Fr. 5: 71. 1889.
Ganoderma mastoporum (Lév.) Pat., Bull. Soc. Mycol. Fr. 5: 75. 1889.
Ganoderma subtornatum Murrill, Bull. Torrey Bot. Club 34: 477. 1907.
Ganoderma pygmoideum Steyaert, Bull. Jard. Bot. État Brux. 32: 103. 1962.
Ganoderma crebrostriatum J.D. Zhao & L.W. Hsu, Acta Mycol. Sin. 2: 161. 1983.
Ganoderma densizonatum J.D. Zhao & X.Q. Zhang, Acta. Mycol. Sin. 5: 86. 1986.
Ganoderma limushanense J.D. Zhao & X.Q. Zhang, Acta. Mycol. Sin. 5: 219. 1986.
Ganoderma diaoluoshanense J.D. Zhao & X.Q. Zhang, Acta Mycol. Sin. 6: 1. 1987.

For a detailed description of *G. orbiforme*, see Ryvarden (2000) and Wang *et al.* (2014).

Notes: *Polyporus orbiformis* was combined as *Ganoderma orbiforme* by Ryvarden (2000), while *G. boninense* and *G. pygmoideum* were considered as synonyms of *G. orbiforme* by Ryvarden (2000). The treatment of *G. boninense* as a synonym of *G. orbiforme* is not accepted by most other mycologists (Pilotti 2005). Wang *et al.* (2014) clarified the taxonomic status of *G. orbiforme* based on morphological and molecular data. *Ganoderma cupreum*, *G. densizonatum*, *G. fornicatum*, *G. limushanense*, *G. mastoporum* and *G. subtornatum* were treated as synonyms of *G. orbiforme* by Wang *et al.* (2014). Cao (2013) regarded *G. crebrostriatum* and *G. diaoluoshanense* as synonyms of *G. mastoporum* based on the observation of holotype specimens, while *G. crebrostriatum* and *G. diaoluoshanense* should be regarded as the synonyms of *G. orbiforme* according to the revision of *G. mastoporum* by Wang *et al.* (2014). In this study, two specimens of *G. cupreum* from Cameroon were included in the phylogenetic analyses, and they formed an independent lineage which is distinct from *G. orbiforme* (Fig. 1). Thus, *G. cupreum* should be treated as an independent species.

Ganoderma philippii (Bres. et Henn.) Bres., Iconogr. Mycol. 21: 1014. 1932. MycoBank MB 314321. Figs 51, 52.
Basionym: *Fomes philippii* Bres. & Henn. ex Sacc., Syll. Fung. (Abellini) 9: 180. 1891.

Description: *Basidiomata* annual or perennial, sessile and broadly attached, sometimes growing together, hard corky. *Pilei* solitary, variable, flabelliform to circular, applanate, up to 26 cm diam and 1.6 cm thick. *Pileal surface* pale brown to purplish black, dull, glabrous, with dense concentric zones; margin acute to obtuse, wavy like petal. *Pore surface* white when fresh, turning darker when bruised, pale brown when dry; pores circular to angular, 5–6 per mm;

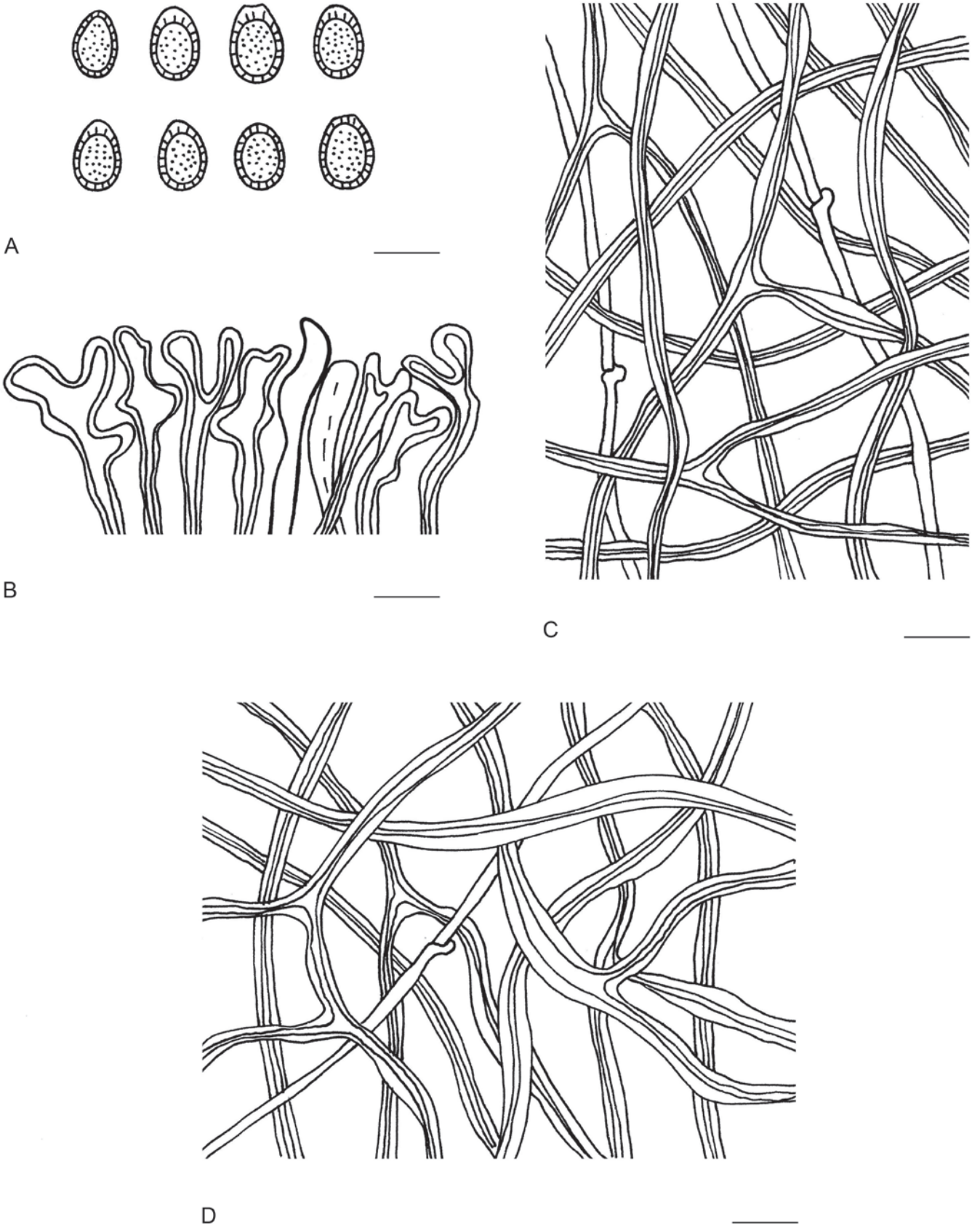

Fig. 50. Microscopic structures of *Ganoderma mutabile* (drawn from Cui 17189). **A.** Basidiospores. **B.** Apical cells from cuticle. **C.** Hyphae from trama. **D.** Hyphae from context. Scale bars = 10 µm.

dissepiments thin, mostly entire. *Context* brown, homogeneous, with black melanoid lines, hard corky, up to 1.4 cm thick. *Tubes* yellowish brown, non-stratified, up to 2 mm long. *Hyphal system* trimitic; generative hyphae with clamp connections; all hyphae IKI –, CB +; tissues darkening in KOH. Generative hyphae in context colourless, thin-walled, 2–3 µm diam; skeletal hyphae in context pale yellowish brown, thick-walled with a narrow lumen or sub-solid, arboriform and flexuous, 3–5 µm diam; binding hyphae in

Fig. 51. Basidiomata of *Ganoderma philippii*.

context colourless, thick-walled, branched and flexuous, 1–2 µm diam. Generative hyphae in tubes colourless, thin-walled, 1–3 µm diam; skeletal hyphae in tubes pale brown to dark brown, thick-walled with a narrow lumen or sub-solid, frequently arboriform and flexuous, 2–5 µm diam; binding in tubes colourless, thick-walled, branched and flexuous, 1–2 µm diam. *Cystidia*, *cystidioles*, *basidia* and *basidioles* absent. *Basidiospores* obovoid, not obviously truncated, with obvious vesicular appendix, pale yellowish brown, IKI –, CB +, double-walled with slightly thick walls, exospore walls smooth, endospore walls with dense spinules, 5–6 × 3–4 µm, L = 5.63 µm, W = 3.38 µm, Q = 1.67 (n = 30/1, with the turgid vesicular appendix excluded); 6–8 × 3–4 µm, L = 7.32 µm, W = 3.36 µm, Q = 2.18 (n = 30/1, with the turgid vesicular appendix included).

Materials examined: **China**, Hainan, Qiongzhong County, Limushan, on stump of *Hevea*, 9 Sep. 2016, Cui 14443 (BJFC029311), Cui 14444 (BJFC029311). **Singapore**, Bukit Timah Nature Reserve, on fallen trunk of angiosperm tree, 19 Jul. 2017, Dai 17828 (BJFC025360).

Notes: *Ganoderma philippii* was firstly described from Myanmar, and it has a wide distribution in South-East Asia including South China, Indonesia, Malaysia and Singapore (Steyaert 1972, Moncalvo & Ryvarden 1997). *Ganoderma philippii* can be distinguished by the sessile basidiomata with variable pilei, pale brown to purplish black pileal surface with dense concentric zones, small and obovoid basidiospores.

Ganoderma sanduense Hapuar. *et al.*, Mycosphere 8: 274. 2019. MycoBank MB 634622.

For a detailed description of *Ganoderma sanduense*, see Hapuarachchi *et al.* (2019b).

Notes: The type locality of *Ganoderma sanduense* is Sandu County of Guizhou Province in southwestern China. *Ganoderma stratoideum* was also described from Sandu County, and it shares layered, reddish black and laccate pilei, moderately sized pores (3–5 per mm), and heterogenous context with *G. sanduense* (He & Yu 1989). However, the small pilei (2–4 × 1–2.5 cm), greyish brown pore surface and larger basidiospores (12.1–13.8 × 9.2–10.5 µm) differentiate *G. sanduense* (Hapuarachchi *et al.* 2019b). The type specimen of *G. stratoideum* has been lost, and its taxonomic status is doubtful.

Ganoderma shanxiense L. Fan & H. Liu, Phytotaxa 406: 132. 2019. MycoBank MB 830632.

For a detailed description of *Ganoderma shanxiense*, see Liu *et al.* (2019).

Notes: *Ganoderma shanxiense* was described from Shanxi Province in China and is characterised by its basidiospores with a tapering and obtuse end at maturity (Liu *et al.* 2019). In the phylogenetic tree, *G. shanxiense* clustered with *G. chuxiongense* (Fig. 1) which

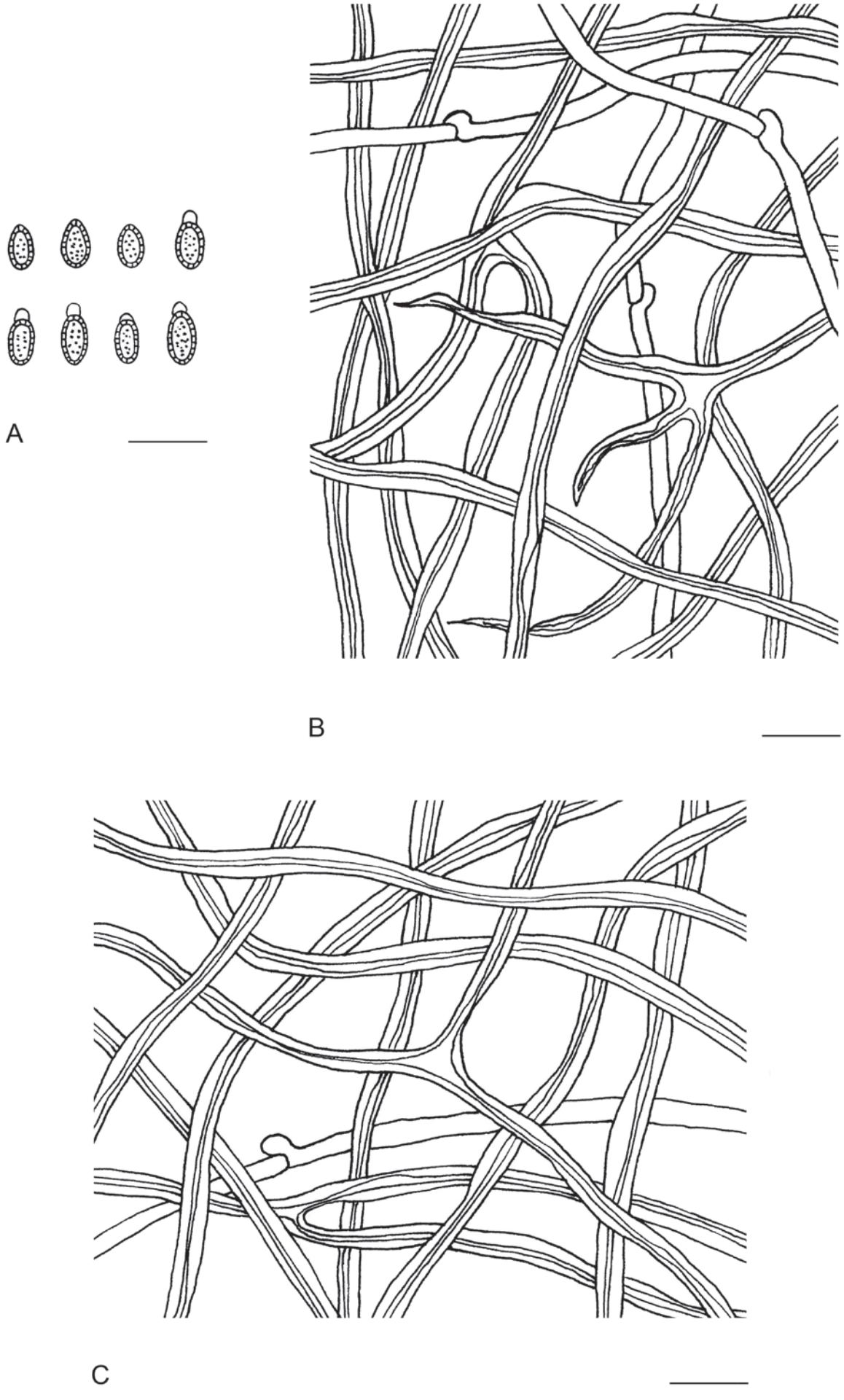

Fig. 52. Microscopic structures of *Ganoderma philippii* (drawn from Cui 14443). **A.** Basidiospores. **B.** Hyphae from trama. **C.** Hyphae from context. Scale bars = 10 µm.

was described from Yunnan Province, but the latter species differs by a purplish black and laccate pileal surface, greyish white pore surface with small pores (7–8 per mm), and broadly ellipsoid to ovoid basidiospores (10–12 × 7–8.5 µm).

Ganoderma sichuanense J.D. Zhao & X.Q. Zhang, Acta. Mycol. Sin. 2: 159. 1983. MycoBank MB 107984.

For a detailed description of *Ganoderma sichuanense*, see Zhao *et al.* (1983) and Wang *et al.* (2012).

Notes: *Ganoderma sichuanense* was first described from Sichuan Province by Zhao *et al.* (1983). Since then, more specimens have been collected from Guangdong, Guangxi of China and Sri Lanka. Phylogenetically, *G. weberianum* grouped with *G. sichuanense* which is consistent with Hapuarachchi *et al.* (2019b). Further studies are needed to clarify the relationship between *G. weberianum* and *G. sichuanense*.

Ganoderma sinense J.D. Zhao *et al.*, Acta Microbiol. Sin. 19: 272. 1979. MycoBank MB 314325. Figs 53, 54.
Synonyms: *Ganoderma austrofujianense* J.D. Zhao *et al.*, Acta Microbiol. Sin. 19: 274. 1979.
Ganoderma luteomarginatum J.D. Zhao *et al.*, Acta Microbiol. Sin. 19: 274. 1979.
Ganoderma formosanum T.T. Chang & T. Chen, Trans. Br. Mycol. Soc. 82: 731. 1984.
Ganoderma guinanense J.D. Zhao & X.Q. Zhang, Acta Mycol. Sin. 6: 4. 1987.
Ganoderma mediosinense J.D. Zhao, Acta Mycol. Sin. 7: 205. 1988.

Description: *Basidiomata* annual, laterally stipitate, hard corky to woody hard. *Pilei* solitary, variable, flabelliform to reniform or circular, up to 14 cm diam and 1.6 cm thick. *Pileal surface* reddish brown to purplish black, strongly laccate, glabrous, with concentric furrows and radial wrinkles; margin acute to obtuse, entire, slightly incurved. *Pore surface* white when fresh, turning darker when bruised, light buff when dry; pores circular to angular, 3–5 per mm; dissepiments thin, mostly entire. *Context* heterogeneous, the upper layer white to buff, the lower layer pale brown to yellowish brown, with black melanoid lines, hard corky, up to 3 cm thick. *Tubes* yellowish brown, non-stratified, up to 1.5 cm long. *Stipe* reddish brown to purplish black, flattened to cylindrical, up to 6 cm long and 2 cm diam. *Hyphal system* trimitic; generative hyphae with clamp connections; all hyphae IKI –, CB +; tissues darkening in KOH. Generative hyphae in context colourless, thin-walled, 2–4 µm diam; skeletal hyphae in context pale yellowish brown, thick-walled with a narrow lumen or sub-solid, arboriform and flexuous, 3–6 µm diam; binding hyphae in context colourless, thick-walled, branched and flexuous, 1.5–2.5 µm diam. Generative hyphae in tubes colourless, thin-walled, 1–3 µm diam; skeletal hyphae in tubes pale brown to dark brown, thick-walled with a narrow lumen or sub-solid, frequently arboriform and flexuous, 2–4 µm diam; binding hyphae in tubes colourless, thick-walled, branched and flexuous, 1–2 µm diam. *Pileipellis* composed of clamped generative hyphae, thick-walled to sub-solid, apical cells clavate, inflated, pale yellow to yellowish brown, about 40–55 × 6–12 µm, forming a

Fig. 53. Basidiomata of *Ganoderma sinense*.

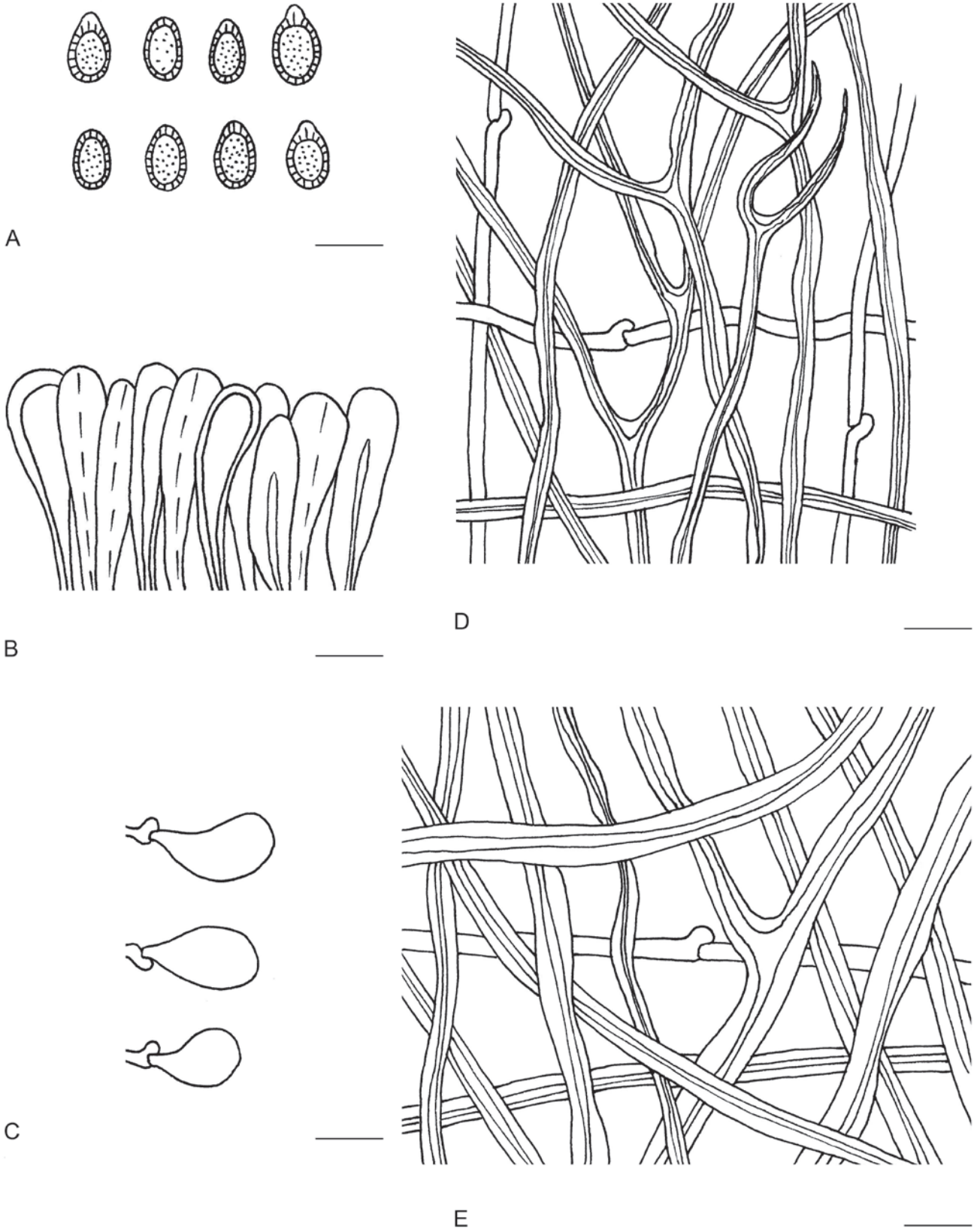

Fig. 54. Microscopic structures of *Ganoderma sinense* (drawn from Cui 14574). **A.** Basidiospores. **B.** Apical cells from cuticle. **C.** Basidioles. **D.** Hyphae from trama. **E.** Hyphae from context. Scale bars = 10 µm.

regular palisade. *Cystidia* and *cystidioles* absent. *Basidia* absent; *basidioles* barrel-shaped to clavate, colourless, thin-walled, 16–24 × 9–12 µm. *Basidiospores* ellipsoid, not obviously truncated, pale yellowish brown, IKI –, CB +, double-walled with moderately thick walls, exospore wall smooth, endospore wall with dense spinules, (11–)11.6–13.2(–13.7) × (7–)7.3–8.5(–8.8) µm, L = 12.39 µm, W = 7.99 µm, Q = 1.74 (n = 30/1, with the turgid vesicular appendix included).

Materials examined: **China**, Hainan, Lingshui County, Diaoluoshan Forest Park, on ground of angiosperm forest, 15 Jun. 2016, Cui 13825 (BJFC028691), Cui 13835 (BJFC028701); Guangxi, Jinxiu County,

Dayaoshan Nature Reserve, on stump of angiosperm tree, 15 Jul. 2017, Cui 14524 (BJFC029393), Cui 14526 (BJFC029395).

Notes: *Ganoderma sinense* was described from Hainan Province by Zhao *et al.* (1979), and it can be easily distinguished in the wild by its laterally stipitate basidiomata with dark reddish brown to purplish black and strongly laccate pileal surface. In this study, *G. sinense* clustered with *G. japonicum* with high support (Fig. 1) which is consistent with previous study by Hapuarachchi *et al.* (2019a). *Ganoderma japonicum* should be treated as a synonym of *G. sinense* temporarily based on the previous description and comments (Moncalvo & Ryvarden 1997, Liao *et al.* 2015, Hapuarachchi *et al.* 2019a). Wang (2005) and Cao (2013) also mentioned that *G. austrofujianense*, *G. formosanum*, *G. guinanense*, *G. luteomarginatum* and *G. mediosinense* are synonyms of *G. sinense* after studying the type specimens.

Ganoderma tropicum (Jungh.) Bres., Annls Mycol. 8: 586. 1910. MycoBank MB 149294. Figs 55, 56.
Basionym: *Polyporus tropicus* Jungh., Verh. Batav. Genootsch. Kunst. Wet. 17: 63. 1838.

Description: *Basidiomata* annual to perennial, usually sessile, sometimes laterally stipitate, hard corky to woody hard. *Pilei* solitary, variable, flabelliform to shell-shaped or circular, up to 17 cm diam and 3 cm thick. *Pileal surface* reddish brown to dark brown, strongly laccate, glabrous, with obvious concentric zones; margin acute to obtuse, entire or sometimes lacerated. *Pore surface* white when fresh, turning darker when bruised, straw yellow when dry; pores circular to angular, 4–6 per mm; dissepiments slightly thick to moderately thick, mostly entire. *Context* dark brown, homogeneous, with black melanoid lines, corky, up to 2.2 cm thick. *Tubes* brown, non-stratified, up to 8 mm long. *Stipe* reddish brown to purplish black, flattened to cylindrical, up to 6 cm long and 1.2 cm diam. *Hyphal system* trimitic; generative hyphae with clamp connections; all hyphae IKI –, CB +; tissues darkening in KOH. Generative hyphae in context colourless, thin-walled, 2.5–3.5 µm diam; skeletal hyphae in context pale yellowish brown, thick-walled with a wide to narrow lumen or sub-solid, frequently arboriform and flexuous, 2.5–6 µm diam; binding hyphae in context colourless, thick-walled, branched and flexuous, 1–2 µm diam. Generative hyphae in tubes colourless, thin-walled, 2–3 µm diam; skeletal hyphae in tubes pale brown to dark brown, thick-walled with a narrow lumen or sub-solid, frequently arboriform and flexuous, 2–4 µm diam; binding hyphae in tubes colourless, thick-walled, branched and flexuous, 0.5–1 µm diam. *Pileipellis* composed of clamped generative hyphae, thick-walled to sub-solid, apical cells clavate, sometimes branched or protuberant, inflated and flexuous, yellowish brown, about 19–32 × 4–9 µm, forming a regular palisade. *Cystidia*, *cystidioles*, *basidia* and *basidioles* absent. *Basidiospores* ellipsoid, truncated, pale yellowish brown, IKI –, CB +, double-walled with slightly thick walls, exospore walls smooth, endospore walls with dense spinules, (6.5–)7–8.5(–9) × (4.5–)5–6(–6.5) µm, L = 7.73 µm, W = 5.66 µm, Q = 1.37 (n = 30/1, with the turgid vesicular appendix excluded); (6.8–)7–9.6(–10) × (4–)4.5–6.2(–6.4) µm, L = 8.90 µm, W = 5.56 µm, Q = 1.60 (n = 30/1, with the turgid vesicular appendix included).

Materials examined: **China**, Hainan, Haikou, Jinniuling Park, on stump of *Acac*ia, 7 Jun. 2016, Dai 16434 (BJFC022551); Guangdong, Maoming, Dianbai, on dead tree of *Casuarina*, 3 Jun. 2019, Dai 19679 (BJFC031355); Guangxi, Baise, Baise Uprising Memorial Park, on living tree of *Acacia*, 1 Jul. 2019, Cui 20029 (BJFC031703). **Sri Lanka**, Colombo, Dombagaskarda Forest Reserve, on living tree of angiosperm, 27 Feb. 2019, Dai 19491 (BJFC031171). **Vietnam**, Ho Chi Minh City, Botanical Garden, on living tree of *Diospyros bejandii*, 11 Oct. 2017, Cui 16369 (BJFC029668).

Fig. 55. Basidiomata of *Ganoderma tropicum*.

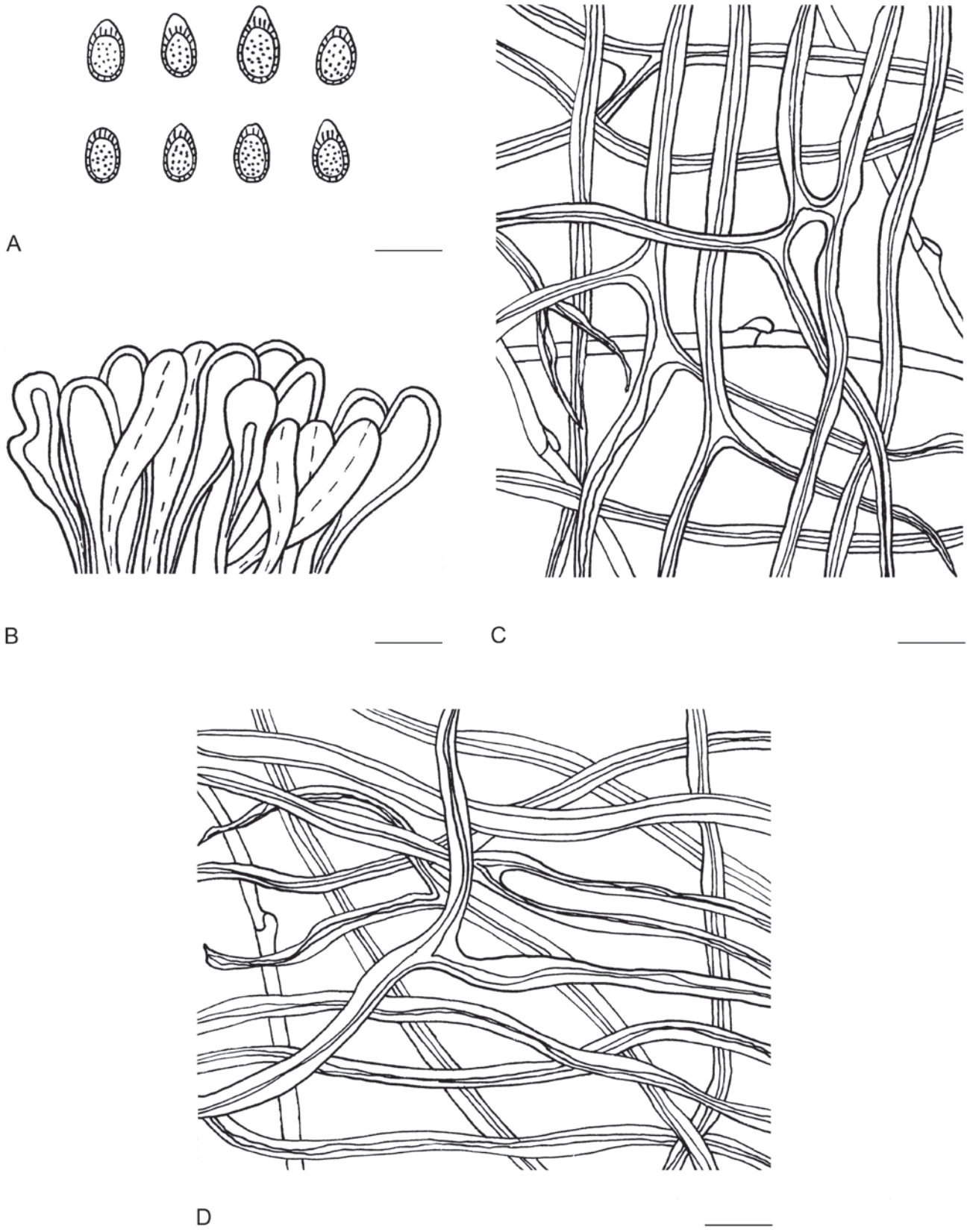

Fig. 56. Microscopic structures of *Ganoderma tropicum* (drawn from Cui 16341). **A.** Basidiospores. **B.** Apical cells from cuticle. **C.** Hyphae from trama. **D.** Hyphae from context. Scale bars = 10 µm.

Notes: *Ganoderma tropicum* was described from Indonesia, and it is characterised by the sessile to woody hard basidiomata, a strongly laccate pileal surface with obvious concentric zones, dark brown context, sometimes branched or protuberant apical cells of pileipellis, and ellipsoid basidiospores with dense spinules on the endospore walls (Steyaert 1972, Ryvarden 1981). These features are consistent with the observation in this study, and all specimens used in the phylogenetic analysis clustered together with high support (Fig. 1).

Ganoderma tsugae Murrill, Bull. Torrey Bot. Club 29: 601. 1902. MycoBank MB 239416. Figs 57, 58.

Description: *Basidiomata* annual, laterally stipitate, hard corky to woody hard. *Pilei* solitary, flabelliform, up to 20 cm diam and 4 cm thick. *Pileal surface* pale yellowish brown to reddish brown, strongly laccate, glabrous, with distinct concentric furrows and slightly radial wrinkles; margin acute to obtuse, lacerated like petals, slightly incurved when dry. *Pore surface* white when fresh, turning darker when bruised, pale yellowish brown when dry; pores circular to angular, 4–6 per mm; dissepiments moderately thick, mostly entire. *Context* heterogeneous, the upper layer white, the lower layer pale brown to yellowish brown, without black melanoid lines, hard corky, up to 2.2 cm thick. *Tubes* yellowish brown, non-stratified, up to 1.5 cm long. *Stipe* reddish brown to purplish black, flattened to cylindrical, up to 6 cm long and 2 cm diam. *Hyphal system* trimitic; generative hyphae with clamp connections; all hyphae IK I–, CB +; tissues darkening in KOH. Generative hyphae in context colourless, thin-walled, 2–3 µm diam; skeletal hyphae in context pale yellowish brown, thick-walled with a narrow lumen or sub-solid, arboriform and flexuous, 2.5–6.5 µm diam; binding hyphae in context colourless, thick-walled, branched and flexuous, 0.5–2 µm diam. Generative hyphae in tubes colourless, thin-walled, 1.5–3 µm diam; skeletal hyphae in tubes pale brown to dark brown, thick-walled with a narrow lumen or sub-solid, frequently arboriform and flexuous, 1.5–4 µm diam; binding hyphae in tubes colourless, thick-walled, branched and flexuous, 0.5–2 µm diam. *Pileipellis* composed of clamped generative hyphae, thick-walled, apical cells clavate, inflated, yellowish brown, about 30–45 × 5–10 µm, forming a regular palisade. *Cystidia* and *cystidioles* absent. *Basidia* barrel-shaped, colourless, thin-walled, 22–28 × 12–18 µm; *basidioles* broadly clavate, colourless, thin-walled, 18–23 × 11–14 µm. *Basidiospores* ellipsoid, truncated, pale yellowish brown, IKI –, CB +, double-walled with moderately thick walls, exospore walls smooth, endospore walls with dense spinules, 8–10(–11) × 5–6.2 µm, L = 9.12 µm, W = 5.49 µm, Q = 1.66 (n = 30/1, with the turgid vesicular appendix excluded); 9–11(–12) × 5–6(–7) µm, L = 10.21 µm, W = 5.88 µm, Q = 1.74 (n = 30/1, with the turgid vesicular appendix included).

Materials examined: **China**, Jilin, Fusong County, Songjianghe Forest Park, on stump of *Larix*, 2 Aug. 2016, Cui 14110 (BJFC028978), Cui 14112 (BJFC028980); Xinjiang, Habahe County, Baihabahe Forest Park, on stump of *Larix*, 10 Sep. 2015, Dai 15851 (BJFC019952), Dai 15856 (BJFC019957). **USA**, Connecticut, on living tree of *Tusga*, 19 Jul. 2012, Dai 12751b (BJFC013059).

Notes: *Ganoderma tsugae* was described from the USA growing on *Tsuga canadensis* by Murrill (1902); it has been reported occurring on several genera of coniferous trees such as *Abies*, *Larix*, *Picea* and *Tsuga* (Steyaert 1980, Adaskaveg & Gilbertson 1986). *Ganoderma tsugae* grouped in the *G. lucidum* complex in the phylogenetic analyses (Fig. 1).

Ganoderma weberianum (Bres. & Henn. ex Sacc.) Steyaert, Persoonia 7: 79. 1972. MycoBank MB 314330. Figs 59, 60.

Fig. 57. Basidiomata of *Ganoderma tsugae*.

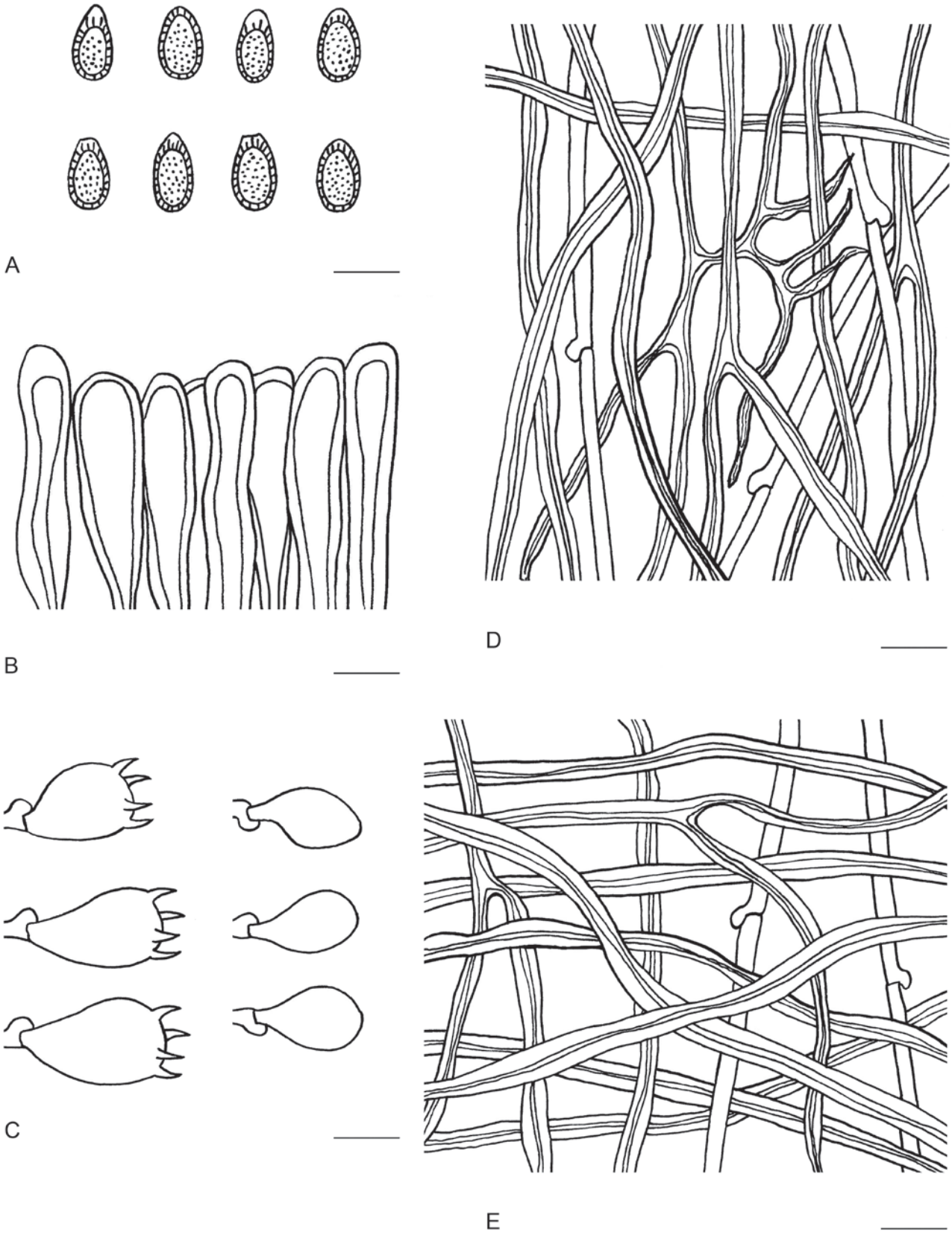

Fig. 58. Microscopic structures of *Ganoderma tsugae* (drawn from Cui 14554). **A.** Basidiospores. **B.** Apical cells from cuticle. **C.** Basidia and basidioles. **D.** Hyphae from trama. **E.** Hyphae from context. Scale bars = 10 μm.

Basionym: *Fomes weberianus* Bres. & Henn. ex Sacc., Syll. Fung. (Abellini) 9: 174. 1891.
Synonyms: *Ganoderma microsporum* R.S. Hseu, Mycotaxon 35: 36. 1989.
Ganoderma tenue J.D. Zhao *et al.*, Acta Microbiol. Sin. 19: 271. 1979.

Description: *Basidiomata* annual, sessile or with short stipe, usually growing together, imbricate, hard corky to woody hard. *Pilei* solitary, flabelliform, applanate, up to 14 cm diam and 8 mm thick. *Pileal surface* reddish brown to purplish black or near black, strongly laccate, glabrous, with concentrical bands and slightly radial wrinkles; margin acute, lacerated like petal, slightly incurved when

Fig. 59. Basidiomata of *Ganoderma weberianum*.

dry. *Pore surface* white when fresh, turning darker when bruised, pale yellow when dry; pores circular to angular, 4–6 per mm; dissepiments thin to slightly thick, mostly entire. *Context* greyish brown, homogeneous, without black melanoid lines, hard corky, up to 2 mm thick. *Tubes* pale brown to pale grey, non-stratified, up to 6 mm long. *Hyphal system* trimitic; generative hyphae with clamp connections; all hyphae IKI –, CB +; tissues darkening in KOH. Generative hyphae in context colourless, thin-walled, 2–4 µm diam; skeletal hyphae in context pale yellowish brown, thick-walled with a wide to narrow lumen or sub-solid, frequently arboriform and flexuous, 2.5–7 µm diam; binding hyphae in context colourless, thick-walled, branched and flexuous, 2–3 µm diam. Generative hyphae in tubes colourless, thin-walled, slightly swollen at the distal end, 2–3.5 µm diam; skeletal hyphae in tubes pale brown to dark brown, thick-walled with a narrow lumen or sub-solid, frequently arboriform and flexuous, 2–4.5 µm diam; binding hyphae in tubes colourless, thick-walled, branched and flexuous, 1.5–3 µm diam. *Pileipellis* composed of clamped generative hyphae, thick-walled to sub-solid, apical cells clavate, inflated, golden yellow, about 60–90 × 6–12 µm, forming a regular palisade. *Cystidia* and *cystidioles* absent. *Basidia* barrel-shaped, colourless, thin-walled, 15–35 × 13–18 µm; *basidioles* in shape like the basidia, colourless, thin-walled, 14–25 × 9–15 µm. *Basidiospores* subglobose to broadly ellipsoid, not obviously truncated, pale yellowish brown, IKI –, CB +, double-walled with slightly thick walls, exospore wall smooth, endospore wall with dense spinules, 6–7 × 4–6 µm, L = 6.53 µm, W = 5.13 µm, Q = 1.27 (n = 30/1, with the turgid vesicular appendix excluded).

Materials examined: **China**, Guangdong, Yangjiang, Jinshan Botanical Garden, on rotten stump of angiosperm tree, 3 Jun. 2019, Dai 19673 (BJFC031349); Maoming, Dianbai Region, on living tree of *Casuarina*, 3 Jun. 2019, Dai 19682 (BJFC031358); Zhanjiang, Guangdong Ocean University (Huguang Campus), on living tree of *Cinnamomum*, 4 Jun. 2019, Dai 19689 (BJFC031365). **Vietnam**, Ho Chi Minh City, United Palace Park, on living tree of *Cynometra dongnaiensis*, 10 Oct. 2017, Cui 16359 (BJFC029658), Cui 16360 (BJFC029659).

Notes: *Ganoderma weberianum* was first described from the Samoa Islands, and it probably has a worldwide tropical distribution (Steyaert 1972). Moncalvo *et al.* (1995) and Smith & Sivasithamparam (2003) mentioned that the ITS sequences of *G. weberianum* is almost the same to *G. microsporum* and suggested that *G. microsporum* should be treated as a synonym of *G. weberianum*. Cao (2013) regarded *Ganoderma tenue* as a synonym of *G. weberianum* based on the similar morphological characters such as reddish brown to purplish black pileal surface, apical cells of pileipellis regularly palisaded, and subglobose to broadly ellipsoid basidiospores.

Ganoderma weixiense Karun. & J.C. Xu, Phytotaxa 423: 78. 2019. MycoBank MB 646645.

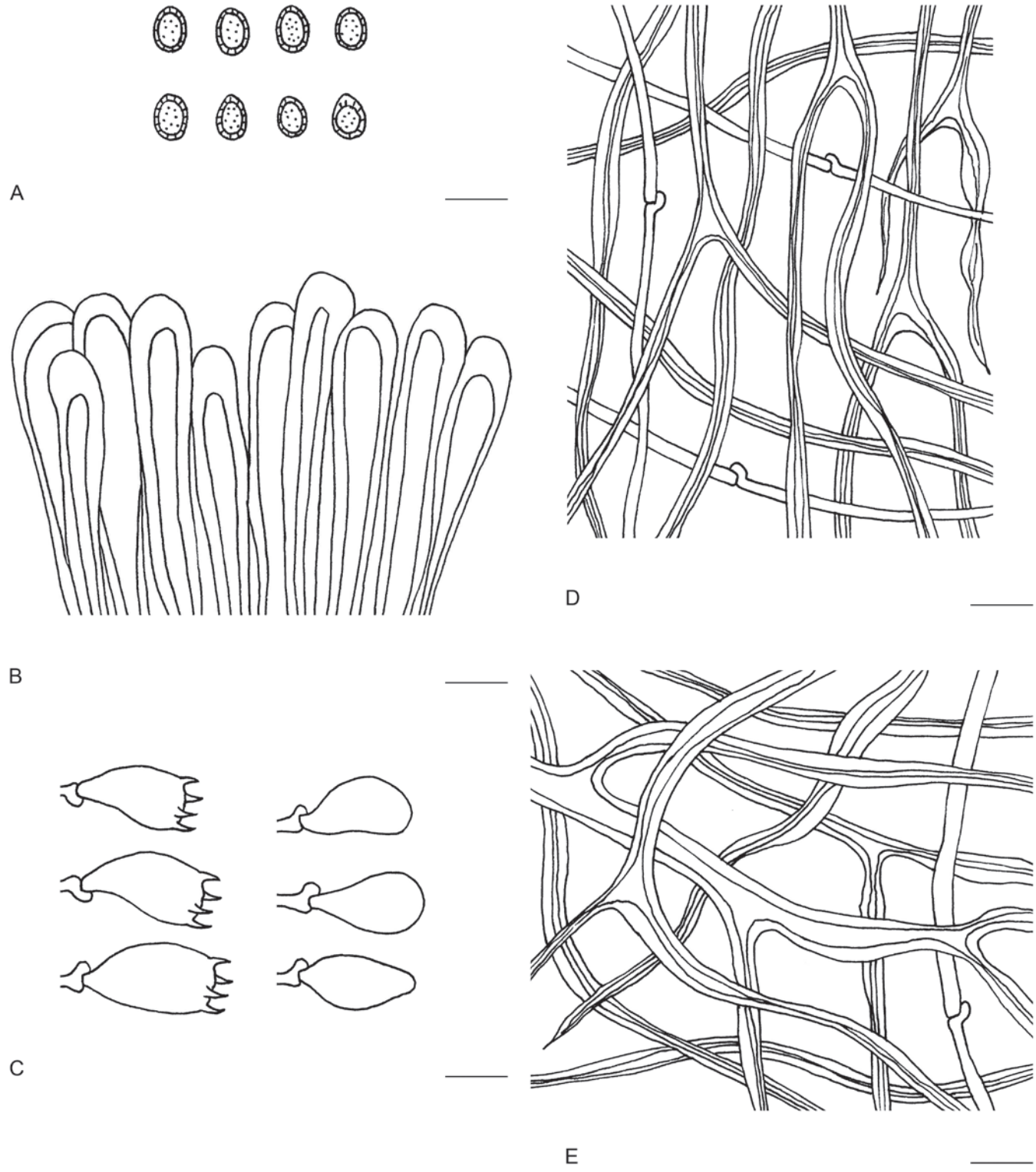

Fig. 60. Microscopic structures of *Ganoderma weberianum* (drawn from Cui 16360). **A.** Basidiospores. **B.** Apical cells from cuticle. **C.** Basidia and basidioles. **D.** Hyphae from trama. **E.** Hyphae from context. Scale bars = 10 µm.

For a detailed description of *Ganoderma weixiense*, see Ye *et al.* (2019).

Notes: *Ganoderma weixiense* was described from high altitude areas (altitude > 2 000 m) of Weixi County and Jinning in Yunnan Province. *Ganoderma leucocontextum* has similar morphological characters and close phylogenetic relationship with *G. weixiense* except the size of pores and basidiospores (details in notes of *G. leucocontextum*). In addition, *G. leucocontextum* shares similar climate and altitude habits with *G. weixiense*. In the current study, these two species grouped together, and it is quite difficult to separate them in morphology, ecology and phylogeny. The taxonomic status of *G. weixiense* needs to be clarified in further studies.

Ganoderma williamsianum Murrill, Bull. Torrey Bot. Club 34: 478. 1907. MycoBank MB 141987.
Synonym: *Ganoderma meijiangense* J.D. Zhao, Acta Mycol. Sin. 7: 16. 1988.

For a detailed description of *Ganoderma williamsianum*, see Wang &Wu (2010).

Notes: *Ganoderma williamsianum* was described from the Philippines and is easily confused with *G. acontextum*, *G. australe* and other non-laccate *Ganoderma* species in the wild as they all shared a hard and dull pileal surface. *Ganoderma williamsianum* is widely distributed in tropical areas of the Philippines, China, Malaysia, Singapore, Sri Lanka, Thailand and Vietnam. Wang & Wu (2010) studied specimens of *G. williamsianum* collected from Hainan and Yunnan provinces in China and the type specimen of *G. meijiangense*, and the latter was treated as a synonym of *G. williamsianum*.

Key to accepted species of *Ganoderma* in China

1a. Endospore wall smooth 2
1b. Endospore wall ornamented 3

2a. Basidiomata annual, pileal surface chestnut-colour, tubes non-stratified ..... *G. castaneum*
2b. Basidiomata perennial, pileal surface greyish brown, tubes stratified ..... *G. yunlingense*

3a. Pileal surface dull 4
3b. Pileal surface laccate 13

4a. Pilei imbricate, margin lacerated like petals ..... *G. puerense*
4b. Pilei solitary, margin entire 5

5a. Basidiospores subglobose ..... *G. hoehnelianum*
5b. Basidiospores broadly ellipsoid to ellipsoid or ovoid 6

6a. Tubes stratified 7
6b. Tubes non-stratified 8

7a. Context homogeneous; basidiospores 5.5–7 × 4.1–5.2 µm ..... *G. applanatum*
7b. Context heterogeneous; basidiospores 7–12 × 5–8 µm ..... *G. australe*

8a. Pores < 4 per mm ..... *G. tongshanense*
8b. Pores > 4 per mm 9

9a. Context without black melanoid lines; apical cells in cuticle branched ..... *G. ellipsoideum*
9b. Context with black melanoid lines; apical cells in cuticle unbranched 10

10a. Distributed in higher altitudes ..... *G. alpinum*
10b. Distributed in lower altitudes 11

11a. Apical cells in cuticle irregularly branched or with protuberances ..... *G. williamsianum*
11b. Apical cells in cuticle unbranched or without protuberances 12

12a. Pileal surface reddish brown to greyish brown, pores angular ..... *G. gibbosum*
12b. Pileal surface greyish brown to nearly black, pores circular ..... *G. guangxiense*

13a. Basidiomata sessile 14
13b. Basidiomata stipitate or with constricted short stipe 17

14a. Basidiospores almond-shaped ..... *G. angustisporum*
14b. Basidiospores ellipsoid to ovoid 15

15a. Apical cells in cuticle irregularly branched or with protuberances ..... *G. mutabile*
15b. Apical cells in cuticle unbranched or without protuberances 16

16a. Basidiomata small, pileal surface yellowish brown to reddish brown; basidiospores > 4 µm in width ..... *G. bubalinomarginatum*
16b. Basidiomata large, pileal surface dark brown to near black; basidiospores < 4 µm in width ..... *G. philippii*

17a. Pores < 3 per mm ..... *G. magniporum*
17b. Pores > 3 per mm 18

18a. Pileal surface nearly black 19
18b. Pileal surface pale brown to yellowish brown or reddish brown 23

19a. Stipe short or constricted at base, < 4 cm in length 20
19b. Stipe obviously long, > 4 cm in length 21

20a. Basidiospores subglobose to broadly ellipsoid, < 6 µm in width ..... *G. weberianum*
20b. Basidiospores broadly ellipsoid to ellipsoid or ovoid, > 6 µm in width ..... *G. orbiforme*

21a. Basidiospores truncated ..... *G. sanduense*
21b. Basidiospores not obviously truncated 22

22a. Pore surface grey to pale brown, pores 5–6 per mm; basidiospores 8–11 × 5.5–7 µm ..... *G. ahmadii*
22b. Pore surface white to buff, pores 3–5 per mm; basidiospores 11.6–13.2 × 7.3–8.5 µm ..... *G. sinense*

23a. Pore surface yellowish when fresh 24
23b. Pore surface white to cream or greyish white when fresh 25

24a. Pilei lobate, with dark red pileal surface ..... *G. chuxiongense*
24b. Pilei semicircle, shell-like, reniform to circular, with yellowish brown to reddish brown pileal surface ..... *G. lingzhi*

25a. Distributed in temperate or subtropical areas 26
25b. Distributed in subtropical or tropical areas 31

26a. Context white to cream ..... *G. leucocontextum*
26b. Context buff to brown 27

27a. Growing on coniferous trees ..... *G. tsugae*
27b. Growing on broad-leaf trees 28

28a. Basidiospores < 4 µm in width ..... *G. weixiense*
28b. Basidiospores > 4 µm in width 29

29a. Context with black melanoid lines ..... *G. sichuanense*
29b. Context without black melanoid lines 30

30a. Context heterogeneous; basidiospores 9–11 × 5.5–7 µm ..... *G. lucidum*
30b. Context homogeneous; basidiospores 11–13 × 8–9.5 µm ..... *G. shanxiense*

31a. Stipe short or constricted at base, < 6 cm in length 32
31b. Stipe obviously long, > 6 cm in length 34

32a. Growth on palm trees ..... *G. boninense*
32b. Growth on other trees 33

33a. Basidiomata small; apical cells in cuticle unbranched, basidiospores 10.7–12.8 × 5.7–9 µm ..... *G. subangustisporum*
33b. Basidiomata large; apical cells in cuticle branched or with protuberances, basidiospores 7–9.6 × 4.5–6.2 µm ..... *G. tropicum*

34a. Basidiomata laterally stipitate 35
34b. Basidiomata dorso-laterally stipitate 36

35a. Pilei solitary ..... *G. casuarinicola*
35b. Pilei imbricate ..... *G. multipileum*

36a. Context homogeneous, without black melanoid lines ..... *G. subflexipes*
36b. Context heterogeneous, with black melanoid lines 37

37a. Basidiospores larger, 8.5–12.6 × 7.2–9.1 µm ..... *G. calidophilum*
37b. Basidiospores smaller, 7–9 × 4.8–5.5 µm ..... *G. flexipes*

Haddowia Steyaert, Persoonia 7: 108. 1972. MycoBank MB 17717.

Type species: *Haddowia longipes* (Lév.) Steyaert

Description: *Basidiomata* annual, laterally stipitate, corky. *Pilei* solitary, sub-orbicular to flabelliform. *Pileal surface* yellowish brown to reddish brown or blackish brown, laccate, tomentose, concentrically zonate and furrowed, radial rugose. *Pore surface* white when fresh becoming straw yellow when dry; pores circular to angular; dissepiments thick, entire. *Context* white, corky. *Hyphal system* trimitic; generative hyphae colourless, thin-walled, with clamp connections; skeletal hyphae colourless to pale yellow, thick-walled, arboriform and flexuous; binding hyphae colourless, sub-solid, branched and flexuous. *Basidiospores* globose to ellipsoid, non-truncated, yellow to pale yellowish brown, double-walled with thick walls, exospore wall smooth and covering longitudinal crests, endospore wall with two longitudinal crests and transverse membranes.

Notes: *Haddowia* has similar basidiomata in shape and colour to *Ganoderma*, but differs by its non-truncated basidiospores which are double and thick-walled, a smooth exospore wall covering longitudinal crests, and an endospore wall with two longitudinal crests and transverse membranes. Although no outer wall on the basidiospores of *Haddowia* was observed by Steyaert (1972), and a smooth exospore wall exists according to the scanning electron micrographs of *Haddowia* species taken by Costa-Rezende *et al.* (2020b) and the current study (Fig. 8 E). In the phylogenetic analyses, *Ha. longipes* and *Ha. macropora* formed a distinct well-supported clade of *Ganodermataceae* (Fig. 1).

Haddowia macropora B.K. Cui, Vlasák & Y.F. Sun, ***sp. nov.*** MycoBank MB 839663. Figs 61, 62.

Diagnosis: Differs from other species in the genus by its yellowish brown to reddish brown pileal surface and large pores.

Etymology: *macropora* (*Lat.*), refers to the large pores.

Typus: **French Guiana** (**holotype** JV 1908/46).

Description: *Basidiomata* annual, laterally stipitate, corky. *Pilei* solitary, sub-orbicular to flabelliform, up to 4 cm diam and 1 mm thick. *Pileal surface* yellowish brown to reddish brown, strongly laccate, glabrous, with obvious concentric furrows and irregularly radial wrinkles; margin obtuse, entire, wavy when dry. *Pore surface* cream when fresh becoming dark when bruised; pores angular to irregular, 1–2 per mm; dissepiments slightly thick, entire. *Context* cream, without dark melanoid lines, soft corky, up to 1.5 mm thick. *Tubes* concolorous with context, up to 8.5 mm long. *Stipe* reddish-brown to purple-black, cylindrical and solid, up to 16.5 cm long and 6 mm diam. *Hyphal system* trimitic; generative hyphae with clamp connections, all the hyphae IKI + (dextrinoid), CB +; tissues darkening in KOH. Generative hyphae in context colourless, thin-walled, 2–3 µm diam; skeletal hyphae in context colourless to pale yellow, thick-walled with a wide to narrow lumen or sub-solid, frequently arboriform and flexuous, 2–5 µm diam; binding hyphae in context colourless, thick-walled, rarely branched and flexuous, 1–1.5 µm diam. Generative hyphae in tubes colourless, thin-walled, 2–3 µm diam; skeletal hyphae in tubes pale yellow, thick-walled with a wide to narrow lumen or sub-solid, frequently arboriform and flexuous, 2–4 µm diam; binding hyphae in tubes colourless, thick-

Fig. 61. Basidiomata of *Haddowia macropora*.

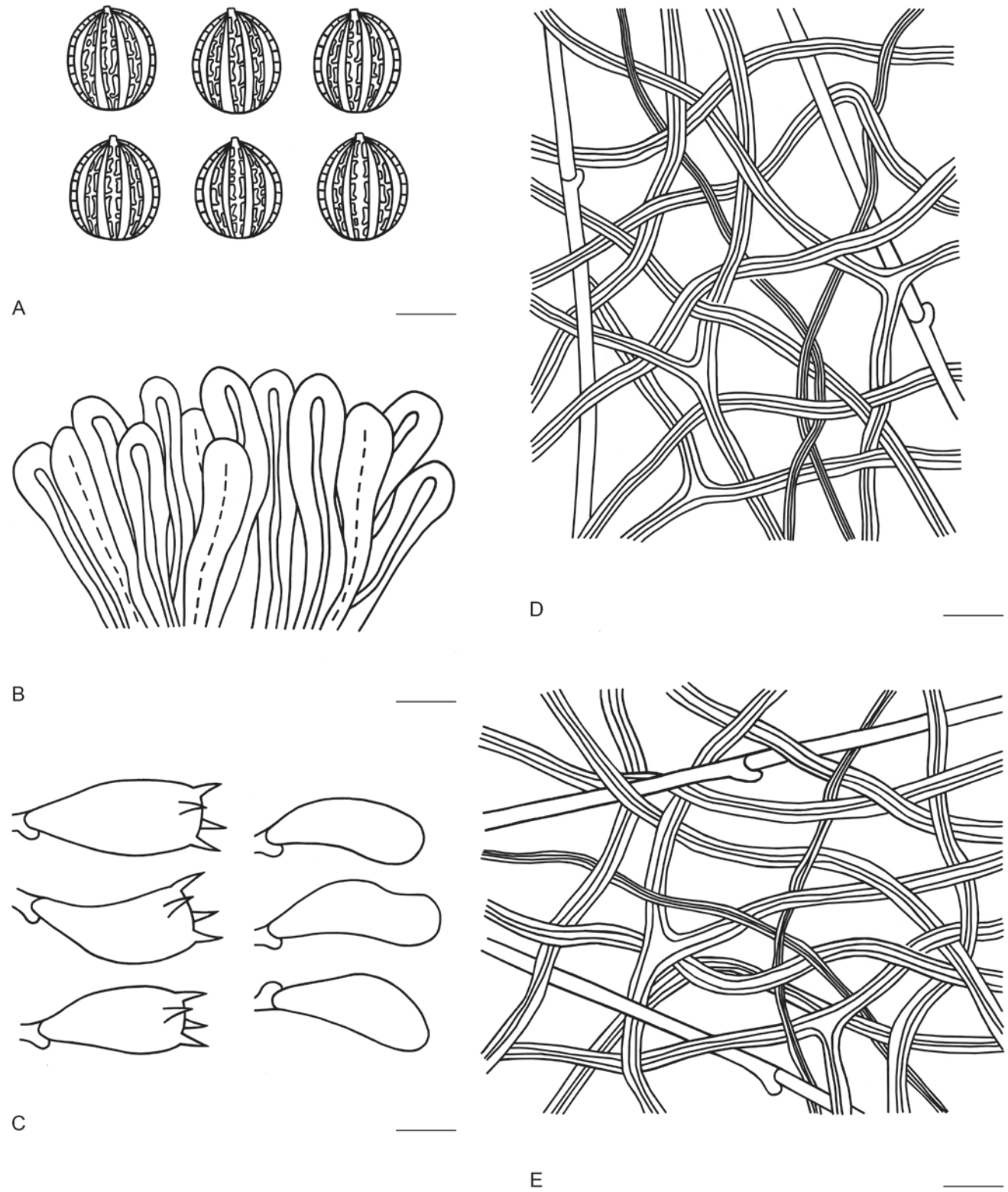

Fig. 62. Microscopic structures of *Haddowia macropora* (drawn from JV 1908/46). **A.** Basidiospores. **B.** Apical cells from cuticle. **C.** Basidia and basidioles. **D.** Hyphae from trama. **E.** Hyphae from context. Scale bars = 10 µm.

walled, rarely branched and flexuous, up to 1.5 µm diam. *Pileipellis* composed of clamped generative hyphae, thick-walled to subsolid, apical cells clavate, inflated and flexuous, yellowish brown, about 32–48 × 6–12 µm, forming a regular palisade. *Cystidia* and *cystidioles* absent. *Basidia* barrel-shaped, colourless, thin-walled, 23–32 × 14–17 µm; *basidioles* clavate, colourless, thin-walled, 21–30 × 7–15 µm. *Basidiospores* subglobose to broadly ellipsoid, pale yellowish brown, IKI + (dextrinoid), CB +, double-walled with distinctly thick walls, exospore wall smooth and covering longitudinal crests, endospore wall with intermittently longitudinal crests and transverse membranes, (13.6–)14–15.5(–16) × (12–)12.3–13.8(–14) µm, L = 14.64 µm, W = 13.08 µm, Q = 1.12 (n = 60/1).

Notes: *Haddowia macropora* has the typical basidiospores of *Haddowia* which differ from other genera in *Ganodermataceae* having intermittently longitudinal crests and transverse membranes on the endospore walls (Steyaert 1972). It can further be

distinguished by the yellowish brown to reddish brown pileal surface, and large pores. *Haddowia longipes* as the type species in this genus is quite different to *Ha. macropora* by the blackish brown pileal surface, thick context (4–5 mm), and ellipsoid basidiospores (12–19 × 10–14.5 µm, Steyaert 1972).

Key to accepted species of *Haddowia*

1a. Pileal surface yellowish brown to reddish brown, context thin (< 1.5 mm) ..... *Ha. macropora*
1b. Pileal surface blackish brown, context thick (4–5 mm) ..... *Ha. longipes*

Humphreya Steyaert, Persoonia 7: 98. 1972. MycoBank MB 17778.

Type species: *Humphreya lloydii* (Pat. & Har.) Steyaert.

For a detailed description of *Humphreya*, see Steyaert (1972).

Notes: *Humphreya* basidiospores have a typical ornamentation of reticulate or disjointed crests on the endospore walls which are different from other genera of *Ganodermataceae* (Steyaert 1972). Until now, *Humphreya* contained three species, *viz*., *Hu. eminii*, *Hu. endertii* and *Hu. lloydii*. No sequence data are available for *Humphreya*; thus, it is not included in the phylogenetic analyses of *Ganodermataceae*.

Key to accepted species of *Humphreya*

1a. Basidiospores more than 20 µm in length ..... *Hu. eminii*
1b. Basidiospores less than 20 µm in length 2

2a. Basidiomata up to 12 cm diam; basidiospores with reticulate ornamentation on the endospore wall ..... *Hu. lloydii*
2b. Basidiomata about 3 cm diam; basidiospores with disjointed crests on the endospore wall ..... *Hu. endertii*

Magoderna Steyaert, Persoonia 7: 111. 1972. MycoBank MB 18011.

Type species: *Magoderna subresinosum* (Murrill) Steyaert

Description: *Basidiomata* annual, sessile or stipitate, woody hard. *Pilei* solitary, sub-orbicular to infundibuliform. *Pileal surface* hair brown to coal black, dull to slightly shiny, glabrous, with concentric furrows and radial wrinkles. *Pore surface* buffy brown to pale grey brown when dry; pores circular to angular; dissepiments thick, entire. *Context* cream to buff, sometimes with dark melanoid lines, woody hard. *Hyphal system* trimitic; generative hyphae colourless, thin-walled, with clamp connections; skeletal hyphae near colourless, sub-solid, arboriform and flexuous; binding hyphae colourless, thick-walled, branched and flexuous. *Basidiospores* ellipsoid to ovoid, non- truncated, pale yellow, double and thick walled, exospore wall faintly verrucose, endospore wall with dense spinules.

Notes: *Magoderna* has a fibrous and pale white context, anticlinal hyphae in pileipellis, and ellipsoid to ovoid basidiospores without a truncated apex. Until now, *M. infundibuliforme* and *M. subresinosum* were accepted in *Magoderna*. In the phylogenetic analyses, the *Magoderna* clade was well supported and grouped with the *Neoganoderma* clade (Fig. 1).

Magoderna subresinosum (Murrill) Steyaert, Persoonia 7: 112. 1972. MycoBank MB 317117. Figs 63, 64.
Basionym: *Fomes subresinosus* Murrill, Bull. Torrey Bot. Club 35: 410. 1908.

Description: *Basidiomata* annual, sessile, woody hard. *Pilei* solitary, flabelliform, up to 12 cm diam and 3 cm thick. *Pileal surface* coal black, slightly shiny, glabrous, sticky, with obvious concentric furrows and strong radial wrinkles; margin subacute to obtuse, entire, incurved when dry. *Pore surface* pale greyish brown when dry; pores circular to angular, 4–5 per mm; dissepiments distinctly thick, entire. *Context* cream to pale wood brown, without dark melanoid lines, woody hard and fibrous, up to 1.3 cm thick. *Tubes* pale yellowish brown, up to 1.6 cm long. *Hyphal system* trimitic; generative hyphae with clamp connections, all hyphae IKI –, CB +; tissues slightly darkening in KOH. Generative hyphae in context colourless, thin-walled, 2–4 µm diam; skeletal hyphae in context colourless, sub-solid, arboriform and flexuous, 2–6 µm diam; binding hyphae in context colourless, thick-walled, branched and flexuous, up to 1 µm diam. Generative hyphae in tubes colourless, thin-walled, 2–3 µm diam; skeletal hyphae in tubes colourless, sub-solid, arboriform and flexuous, 2–4 µm diam; binding hyphae in tubes colourless, thick-walled, branched and flexuous, up to 1 µm diam. *Pileipellis* composed of clamped generative hyphae, thick-walled, apical cells clavate, inflated, dark brown, about 20–35 × 5–9 µm, anticlinal, forming a regular palisade. *Cystidia* and *cystidioles* absent. *Basidia* barrel-shaped, colourless, thin-walled, 20–25 × 18–20 µm; *basidioles* in shape like the basidia, colourless, thin-walled, 18–20 × 11–15 µm. *Basidiospores* ellipsoid to ovoid, non-truncated, pale yellow, IKI –, CB +, double-walled with slightly thick walls, exospore wall faintly verrucose, endospore wall with dense spinules, (14.7–)14.9–17.3(–18) × (9.6–)9.8–11.3(–11.8) µm, L = 15.88 µm, W = 10.52 µm, Q = 1.51 (n = 60/2).

Materials examined: **China**, Guangdong, Maoming, on living tree of *Casuarina*, Jun. 2017, Cui 14579 (BJFC029448), Cui 14580 (BJFC029449), Cui 14581 (BJFC029450). **Malaysia**, Selangor, Kota Damansara, National Forest Reserve, on dead angiosperm tree, 17 Apr. 2018, Dai 18626 (BJFC026914); on stump of angiosperm tree, 6 Dec. 2019, Cui 18262 (BJFC035121), Cui 18280 (BJFC035139).

Fig. 63. Basidiomata of *Magoderna subresinosum*.

Notes: *Magoderna subresinosum* is widely distributed in tropical and subtropical areas of Asia and Africa (Steyaert 1972). The taxonomic status of *M. subresinosum* was controversial for a long time. Humphrey (1938) regarded it as *Ganoderma subresinosum* due to the ganodermoid basidiomata. Corner (1983) suggested it should be placed in *Amauroderma* based on a similar hyphal system and similar basidiospores. However, it can be distinguished by a slightly shiny and sticky coal black pileal surface, pale and fibrous context, ellipsoid to ovoid and non-truncated basidiospores with faintly verrucose exospore wall and dense spinules on the endospore wall.

Key to accepted species of *Magoderna*

1a. Pileal surface snuff brown and dull; basidiospores smaller (9–10.5 × 8–9 µm ..... *M. infundibuliforme*
1b. Pileal surface coal black and slightly shiny; basidiospores larger (14.9–17.3 × 9.9–11.3 µm) ..... *M. subresinosum*

Neoganoderma B.K. Cui & Y.F. Sun, ***gen. nov.*** MycoBank MB 840978.

Diagnosis: Differs from other genera by its flat to convex pilei with brown pileal surface, cream context, slightly truncated basidiospores with longitudinal ridges on the endospore wall which are equal in length to the basidiospores.

Etymology: *neoganoderma* (*Lat.*), refers to the genus producing *Ganoderma*-like basidiomata and the distribution in the Neotropics.

Type species: *Neoganoderma neurosporum* (J.S. Furtado) B.K. Cui & Y.F. Sun

Description: *Basidiomata* annual, laterally stipitate or sessile, corky. *Pilei* solitary, flat to convex. *Pileal surface* reddish brown to dark brown, dull, glabrous, concentrically zonate and furrowed. *Pore surface* cream to pale cinnamon brown; pores circular. *Context* pallid white or cream, soft corky. *Hyphal system* dimitic; generative hyphae colourless, thin-walled, branched, with clamp connections; skeletal hyphae colourless to pale yellow, terminal arboriform or unbranched. *Basidiospores* ellipsoid, slightly truncated, pale yellow, double and thick-walled, endospore wall with longitudinal ridges which equal in length to the basidiospores.

Notes: So far, *Neoganoderma* includes *N. neurosporum* which has only been collected from Neotropics. The ganoderma-like basidiomata and haddowia-like ornamentation of endospore wall make *Neoganoderma* easily confused with *Ganoderma* and *Haddowia*, but *Neoganoderma* has unique basidiospores with longitudinal ridges on the endospore wall without obvious traverse ridges which are equal in length to the basidiospores. In the

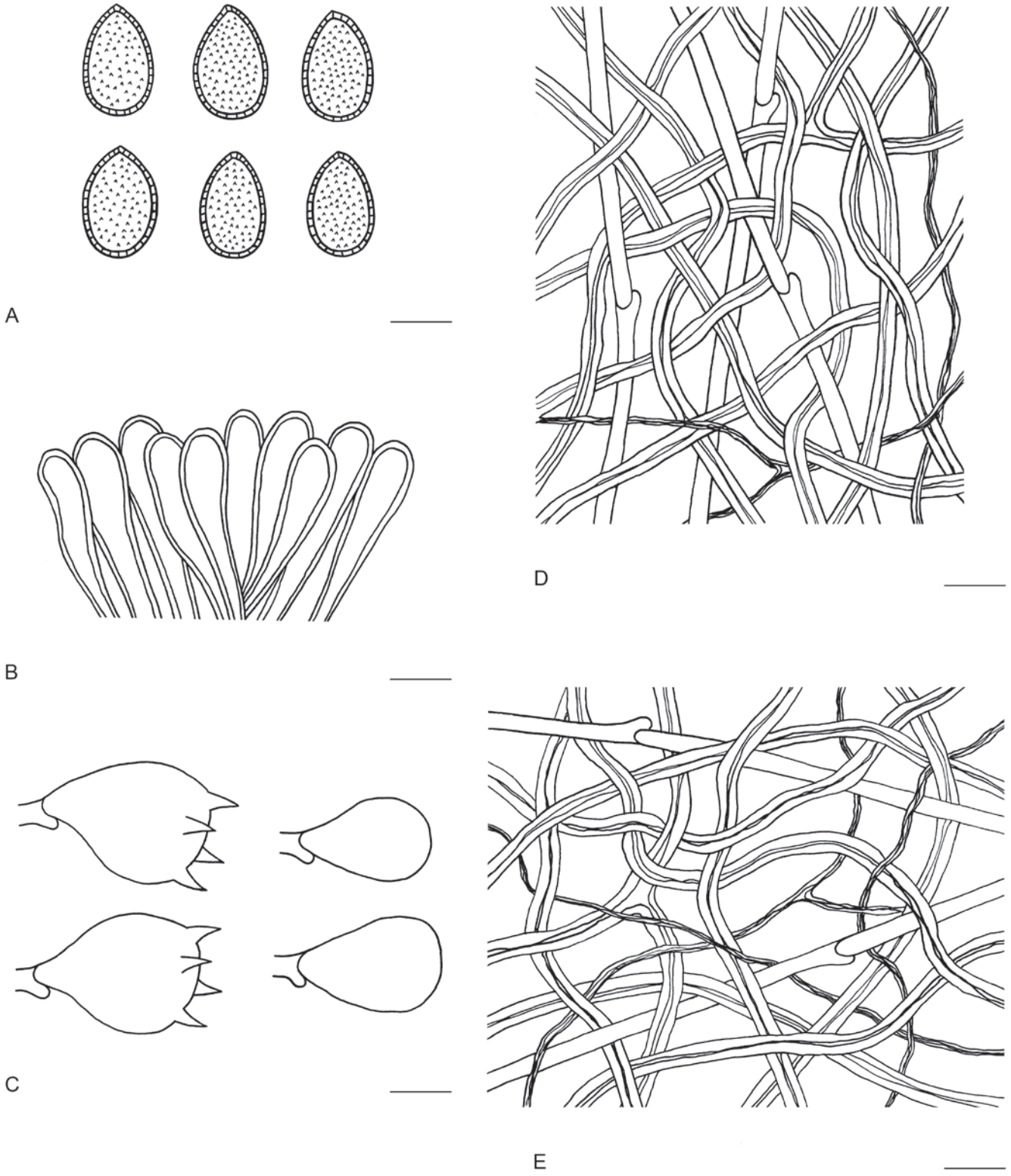

Fig. 64. Microscopic structures of *Magoderna subresinosum* (drawn from Cui 18280). **A.** Basidiospores. **B.** Apical cells from cuticle. **C.** Basidia and basidioles. **D.** Hyphae from trama. **E.** Hyphae from context. Scale bars = 10 µm.

phylogenetic analyses, *Neoganoderma* formed an independent clade distinct from other genera within *Ganodermataceae* and, so far, it is monotypic (Fig. 1).

Neoganoderma neurosporum (J.S. Furtado) B.K. Cui & Y.F. Sun, ***comb. nov.*** MycoBank MB 840979.
Basionym: *Ganoderma neurosporum* Furtado, Persoonia 4: 386. 1967.

Description: *Basidiomata* annual, laterally stipitate or sessile, corky. *Pilei* solitary, flat to convex, up to 15 cm diam and 3 cm thick. *Pileal surface* reddish brown to dark brown, dull, glabrous, with concentric furrows; margin obtuse, entire. *Pore surface* cream to pale cinnamon brown; pores circular, 4–5 per mm. *Context* pallid white or cream, soft corky, up to 2.5 cm thick. *Tubes* pale greyish brown, up to 1.5 cm long. *Stipe* dark brown, slightly swollen at base, up to 10 cm long and 1.5 cm diam. *Hyphal system* dimitic;

generative hyphae with clamp connections, colourless, thin-walled, branched, 2–5 µm diam; skeletal hyphae terminal arboriform or unbranched, colourless to pale yellow, 3–7 µm diam. *Pileipellis* composed of irregularly to slight anticlinal skeletal hyphae and thin generative hyphae. *Basidiospores* ellipsoid, slightly truncated, pale yellow, IKI–, double-walled with thick walls, endospore wall with longitudinal ridges which equal in length to basidiospores, 16–20 × 11–15 µm.

Notes: The brief description of *Neoganoderma neurosporum* was taken from Ryvarden (2004b) and Costa-Rezende *et al.* (2020b). According to the records, *N. neurosporum* is known from dead wood of deciduous trees in Neotropics. *Neoganoderma neurosporum* was placed in *Haddowia* by its similar endospore wall ornamentation, but no obvious traverse ridges were observed in *N. neurosporum* under SEM. Besides, *N. neurosporum* formed an independent lineage in the phylogenetic analyses (Fig. 1). More detailed description of *N. neurosporum* need to be made from future collections.

Sanguinoderma Y.F. Sun *et al.*, Persoonia 44: 224. 2020. MycoBank MB 828433.

Type species: *Sanguinoderma rude* (Berk.) Y.F. Sun *et al*.

For a detailed description of *Sanguinoderma*, see Sun *et al.* (2020).

Notes: *Sanguinoderma* was established by Sun *et al.* (2020) and 10 species were included in this genus. In this study, six new species are described based on the main distinguishing character of *Sanguinoderma i.e*., the fresh pore surface changes rapidly to blood red when bruised; there are other morphological features that differentiate it too.

Sanguinoderma guangdongense B.K. Cui & Y.F. Sun, ***sp. nov.*** MycoBank MB 839664. Figs 65, 66.

Diagnosis: Differs from other species in the genus by its dark pileal surface with shades of brown concentric zones and dense radial lines, fibrous context.

Etymology: *guangdongense* (*Lat.*), refers to the holotype of this species located at Guangdong.

Typus: **China**, Guangdong, Huizhou, on ground, 19 May 2019, Cui 17259 (**holotype** BJFC034117).

Additional materials examined: **China**, Guangdong, Shaoguan, Danxiashan Nature Reserve, on ground, 4 Jun. 2019, Cui 17240 (BJFC034098); Yunnan, Yuxi, Longquan Park, on ground of forest, 16 Aug. 2019, Dai 20419 (BJFC032087). **Thailand**, Chiang Mai, Doi Saket, on ground, 24 Jul. 2016, Dai 16724 (BJFC022831).

Description: *Basidiomata* annual, centrally to laterally stipitate, hard corky to woody hard. *Pilei* solitary, sub-orbicular to umbelliform, up to 8 cm diam and 7 mm thick. *Pileal surface* dark yellowish brown to near black, dull, tomentose, with shades of brown concentric zones and dense radial lines; margin obtuse, entire, wavy and obviously incurved when dry. *Pore surface* pale straw yellow when fresh

Fig. 65. Basidiomata of *Sanguinoderma guangdongense*.

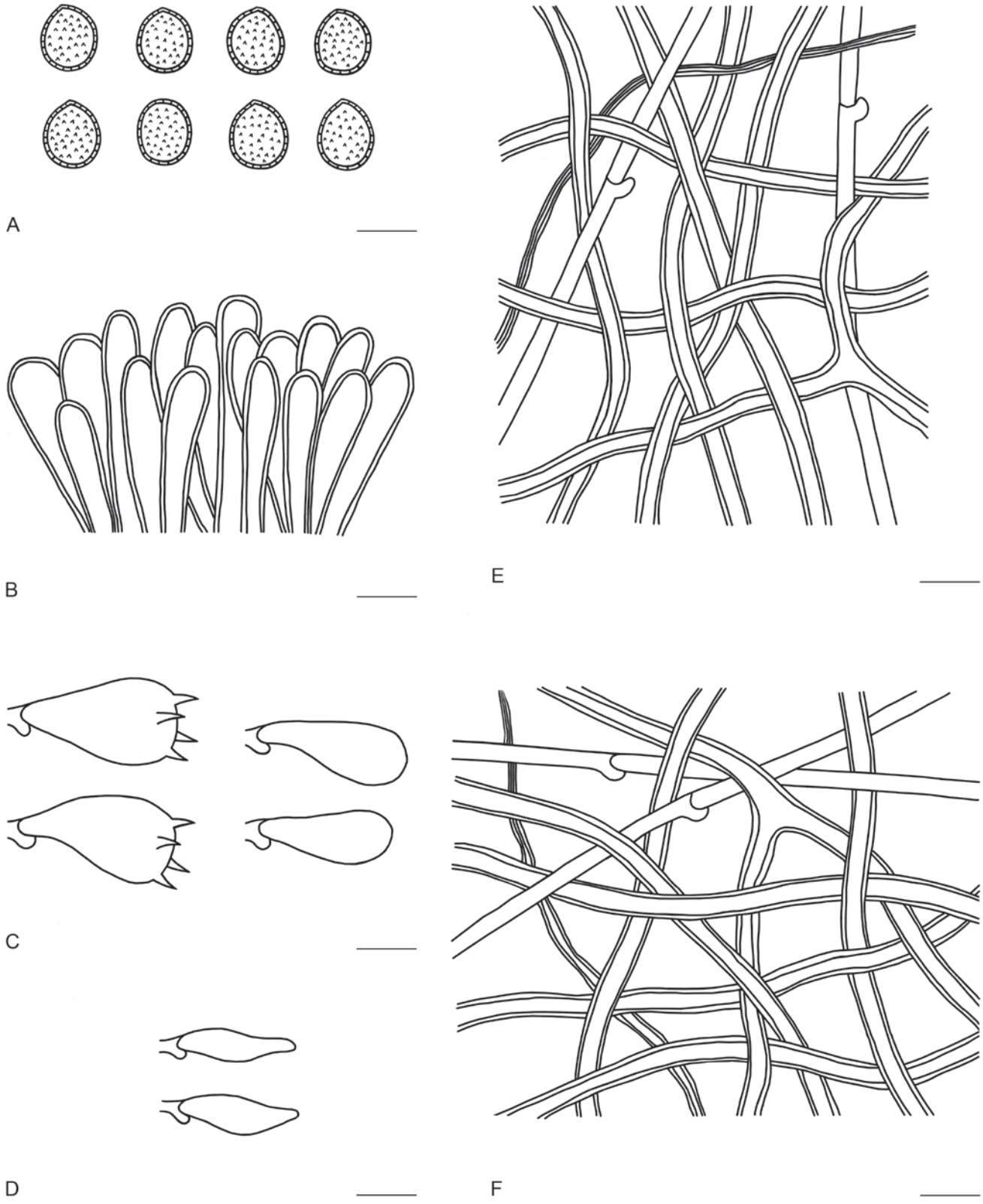

Fig. 66. Microscopic structures of *Sanguinoderma guangdongense* (drawn from Cui 17259). **A.** Basidiospores. **B.** Apical cells from cuticle. **C.** Basidia and basidioles. **D.** Cystidioles. **E.** Hyphae from trama. **F.** Hyphae from context. Scale bars = 10 µm.

becoming blood red when bruised and then quickly darkening; pores circular to angular or irregular, 5–7 per mm; dissepiments slightly thick, entire. *Context* wood brown to dark straw yellow, with dark melanoid lines, hard corky, fibrous, up to 4 mm thick. *Tubes* pale straw yellow to dark yellowish brown, up to 3 mm long. *Stipe* slightly darker than pileal surface, cylindrical and hollow, slightly swollen at base, up to 9.5 cm long and 6 mm diam. *Hyphal system* trimitic; generative hyphae with clamp connections, all hyphae IKI –, CB +; tissues darkening in KOH. Generative hyphae in context colourless, thin-walled, 4–5 µm diam; skeletal hyphae in context pale yellow, thick-walled with a wide lumen, arboriform and flexuous, 3–7 µm diam; binding hyphae in context colourless, thick-walled, rarely branched and flexuous, 1–2 µm diam. Generative hyphae in tubes colourless, thin-walled, 3–4 µm diam; skeletal hyphae in

tubes pale yellow, thick-walled with a wide lumen, arboriform and flexuous, 3–6 µm diam; binding hyphae in tubes colourless, thick-walled, rarely branched and flexuous, up to 2 µm diam. *Pileipellis* composed of clamped generative hyphae, slightly thick-walled, apical cells clavate, faintly inflated, dark yellowish brown, about 28–37 × 6–10 µm, forming a regular palisade. *Cystidia* absent; *cystidioles* fusiform, colourless, thin-walled, 14–20 × 4–7 µm. *Basidia* barrel-shaped to clavate, colourless, thin-walled, 18–25 × 10–15 µm; *basidioles* clavate, colourless, thin-walled, 14–20 × 8–13 µm. *Basidiospores* subglobose to broadly ellipsoid, pale yellow, IKI –, CB +, double-walled with slightly thick walls, exospore wall smooth, endospore wall with dense spinules, (9.4–)9.7–10.8(–11.2) × (8.8–)9–9.8(–10.2) µm, L = 10.26 µm, W = 9.28 µm, Q = 1.1 (n = 60/2).

Notes: *Sanguinoderma guangdongense* can be distinguished by a dark brown to almost black pileal surface with shades of brown concentric zones and dense radial lines. *Sanguinoderma microporum* shares the woody hard basidiomata and similar ornamentation of pilei with *Sa. guangdongense,* but *Sa. microporum* has a pale pileal surface, extremely thick dissepiments of micro pores and larger basidiospores (11–12 × 8.7–9.8 µm, Sun *et al.* 2020).

Sanguinoderma infundibulare B.K. Cui & Y.F. Sun, ***sp. nov.*** MycoBank MB 839665. Figs 67, 68.

Diagnosis: Differs from other species in the genus by its funnel-shaped pilei, yellowish brown to greyish brown pileal surface with dense and radial fine wrinkles.

Etymology: *infundibulare* (*Lat.*), refers to the funnel-shaped pilei.

Typus: **China**, Guangdong, Shaoguan, Danxiashan Nature Reserve, on ground, 4 Jun. 2019, Cui 17248 (**holotype** BJFC034106).

Additional materials examined: **China**, Guangdong, Shaoguan, Danxiashan Nature Reserve, on ground of angiosperm forest, 17 Dec. 2017, Dai 18148 (BJFC025677), Dai 18149 (BJFC025678), Dai 18151 (BJFC025680); 4 Jun. 2019, Cui 17238 (BJFC034096), Cui 17256 (BJFC034114).

Description: *Basidiomata* annual, centrally to laterally stipitate, hard corky. *Pilei* solitary, funnel-shape, up to 7.5 cm diam and 6 mm thick. *Pileal surface* yellowish brown to greyish brown, dull, tomentose, with obvious concentric zones, dense and radial fine wrinkles; margin slightly acute to obtuse, entire and slightly wavy when dry. *Pore surface* greyish white when fresh becoming to blood red when bruised and then quickly darkening; pores circular to angular, 4–6 per mm; dissepiments slightly thick, entire. *Context* pale wood brown to greyish brown, sometimes with dark melanoid lines, corky, up to 4 mm thick. *Tubes* pale grey to greyish brown, up to 2 mm long. *Stipe* concolorous with pileal surface, cylindrical and hollow, slightly swollen at base, up to 10 cm long and 7 mm diam. *Hyphal system* trimitic; generative hyphae with clamp connections, all hyphae IKI –, CB +; tissues darkening in

Fig. 67. Basidiomata of *Sanguinoderma infundibulare*.

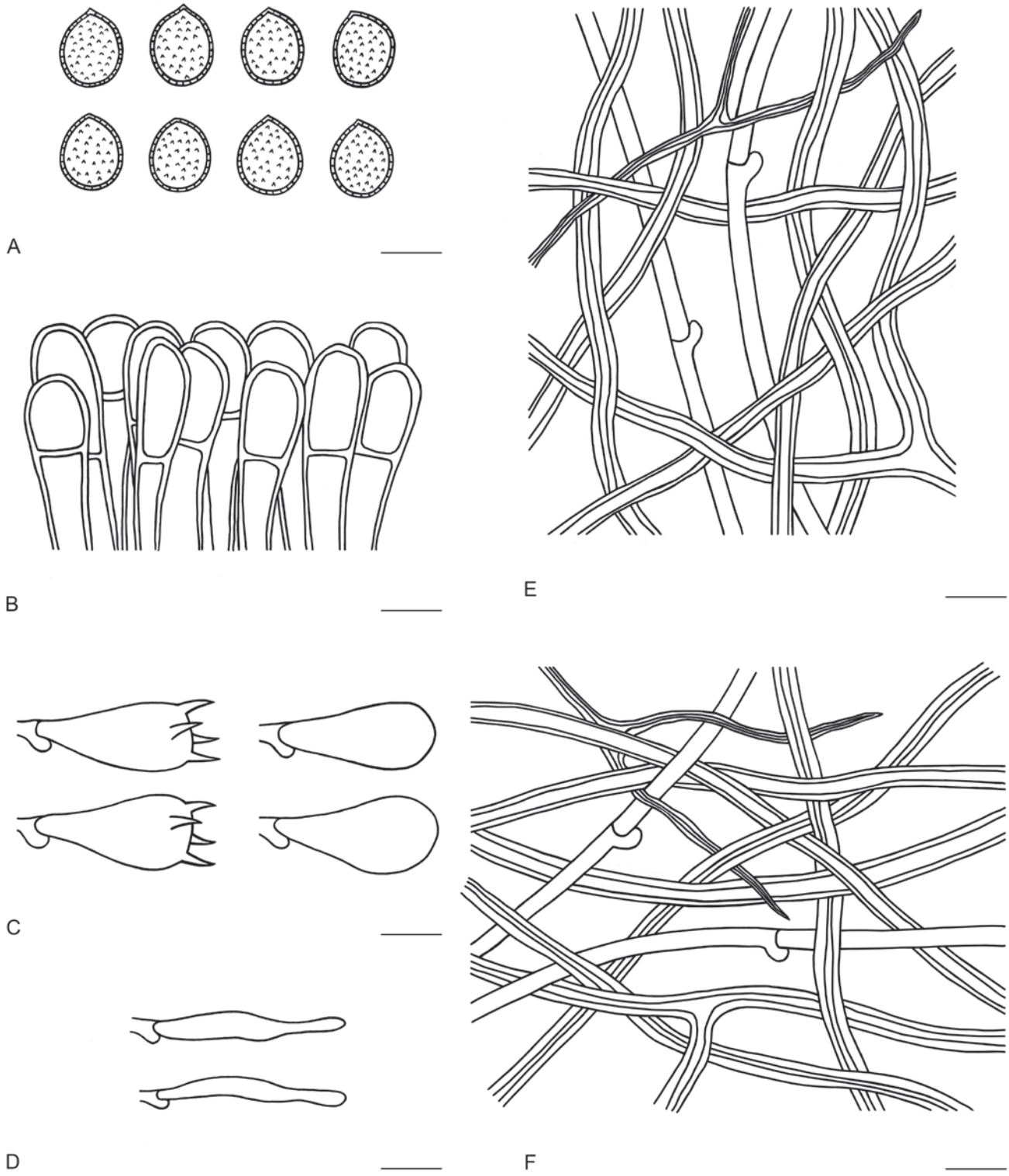

Fig. 68. Microscopic structures of *Sanguinoderma infundibulare* (drawn from Cui 17248). **A.** Basidiospores. **B.** Apical cells from cuticle. **C.** Basidia and basidioles. **D.** Cystidioles. **E.** Hyphae from trama. **F.** Hyphae from context. Scale bars = 10 µm.

KOH. Generative hyphae in context colourless, thin-walled, 3–4 µm diam; skeletal hyphae in context pale yellow, thick-walled with a wide to narrow lumen or sub-solid, arboriform and flexuous, 3–7 µm diam; binding hyphae in context colourless, sub-solid, branched and flexuous, 1–2 µm diam. Generative hyphae in tubes colourless, thin-walled, 3–4 µm diam; skeletal hyphae in tubes pale yellowish brown, thick-walled with a wide to narrow lumen or sub-solid, arboriform and flexuous, 3–6 µm diam; binding hyphae in tubes colourless, sub-solid, branched and flexuous, up to 2 µm diam. *Pileipellis* composed of clamped generative hyphae, thick-walled, apical cells clavate, faintly inflated and with obvious septa, pale yellowish brown, about 23–30 × 6–11 µm, forming a regular palisade. *Cystidia* absent; *cystidioles* clavate and apices constricted, colourless, thin-walled, 20–35 × 2–6 µm. *Basidia* barrel-shaped to clavate, colourless, thin-walled, 22–30 × 14–18 µm; *basidioles* in shape like the basidia, colourless, thin-walled, 15–25 × 9–19 µm. *Basidiospores* subglobose to broadly ellipsoid, pale yellow, IKI –, CB +, double-walled with slightly thick walls, exospore wall smooth, endospore wall with slightly dense spinules, (10–)10.2–12(–12.2) × (8.5–)9–10.2(–10.6) µm, L = 11.04 µm, W = 9.53 µm, Q = 1.16 (n = 60/1).

Notes: *Sanguinoderma infundibulare* was collected from the subtropical areas of China. It is like *Amauroderma preussii* in the thin and funnel-shaped pilei with obvious radial wrinkles, but *A. preussii* was described from Cameroon with darker and incurved pilei when dry, larger pores (2–4 per mm) and smaller basidiospores (7–9.1–11.5 × 6.5–8.5–10 µm, Steyaert 1972, Hapuarachchi *et al.* 2018a).

Sanguinoderma longistipitum B.K. Cui & Y.F. Sun, ***sp. nov.*** MycoBank MB 839666. Figs 69, 70.

Diagnosis: Differs from other species in the genus by basidiomata with small pilei and long stipe.

Etymology: *longistipitum* (*Lat.*), refers to the basidiomata with a long stipe.

Typus: **China**, Yunnan, Honghe, Huanglianshan Forest Park, on ground of forest, 11 Aug. 2019, Dai 20696 (**holotype** BJFC032363).

Additional materials examined: **China**, Yunnan, Jinghong, Xishuangbanna Botanical Garden, on ground, 23 Jul. 2014, Dai 13891 (BJFC017621); Hainan, Ledong County, Jianfengling Nature Reserve, on ground of angiosperm forest, 19 Jun. 2016, Cui 13903 (BJFC028769). **Thailand**, Chiang Rai, Doi Mae Salong, on ground of angiosperm forest, 22 Jul. 2016, Dai 16635 (BJFC022745).

Description: *Basidiomata* annual, laterally stipitate, hard corky. *Pilei* solitary, sub-orbicular to flabelliform, auricular or spathulate, up to 4 cm diam and 5 mm thick. *Pileal surface* greyish brown to almost black, dull, glabrous, with concentric zones and radial wrinkles; margin obtuse, entire, slightly wavy and incurved when dry. *Pore surface* greyish white when fresh becoming to blood red when bruised and then quickly darkening; pores circular to angular, 6–8 per mm; dissepiments moderately thick, entire. *Context* wood brown to greyish brown, sometimes with dark melanoid lines, corky, up to 2 mm thick. *Tubes* dark grey, up to 4 mm long. *Stipe* concolorous with pileal surface, cylindrical and solid, swollen at base, up to 14.5 cm long and 5 mm diam. *Hyphal system* trimitic; generative hyphae with clamp connections, all hyphae IKI –, CB +; tissues darkening in KOH. Generative hyphae in context colourless, thin-walled, 3–4 µm diam; skeletal hyphae in context pale yellow, thick-walled with a wide to narrow lumen or sub-solid, frequently arboriform and flexuous, 3–6 µm diam; binding hyphae in context colourless, sub-solid, branched and flexuous, 1–2 µm diam. Generative hyphae in tubes colourless, thin-walled, 3–4 µm diam; skeletal hyphae in tubes pale yellow, thick-walled with a wide to narrow lumen or sub-solid, arboriform and flexuous, 3–5 µm diam; binding hyphae in tubes colourless, sub-solid, frequently branched and flexuous, up to 2 µm diam. *Pileipellis* composed of clamped generative hyphae, thick-walled, apical cells finger-shape, with multiple obvious septa, pale greyish brown, about 22–40 × 5–10 µm, forming a regular palisade. *Cystidia* absent; *cystidioles* fusiform, colourless, thin-walled, 16–22 × 5–10 µm. *Basidia* barrel-shaped, colourless, thin-walled, 20–27 × 12–17 µm; *basidioles* in shape like the basidia, colourless, thin-walled, 19–25 × 5–16 µm. *Basidiospores* broadly ellipsoid, pale yellow, IKI –, CB +, double-walled with slightly thick walls, exospore wall smooth, endospore wall with dense spinules, 10–11(–11.3) × (8–)8.4–9.6(–9.8) µm, L = 10.58 µm, W = 8.94 µm, Q = 1.18–1.19 (n = 60/2).

Notes: *Sanguinoderma longistipitum* is a distinct species on account of its auricular or spathulate pilei with a long stipe. *Sanguinoderma guangdongense* has a similar distribution with *Sa. longistipitum* which can be collected from Yunnan Province, but the former can be distinguished by larger basidiomata with sub-orbicular to umbelliform pilei, shorter stipe and subglobose basidiospores. *Sanguinoderma longistipitum* is similar with the small specimens of *Sa. rugosum*, which also have broadly ellipsoid basidiospores in similar size (10.2–11.3 × 8.3–9.2 µm, Sun et al. 2020). However, the longer stipe and fusiform cystidioles of *Sa. longistipitum* distinguish it from *Sa. rugosum*. *Amauroderma auriscalpium* which was described from the Neotropics has similar-shaped pilei, but the basidiospores in *A. auriscalpium* are subglobose and smaller (6–8 µm, Torrend 1920).

Fig. 69. Basidiomata of *Sanguinoderma longistipitum*.

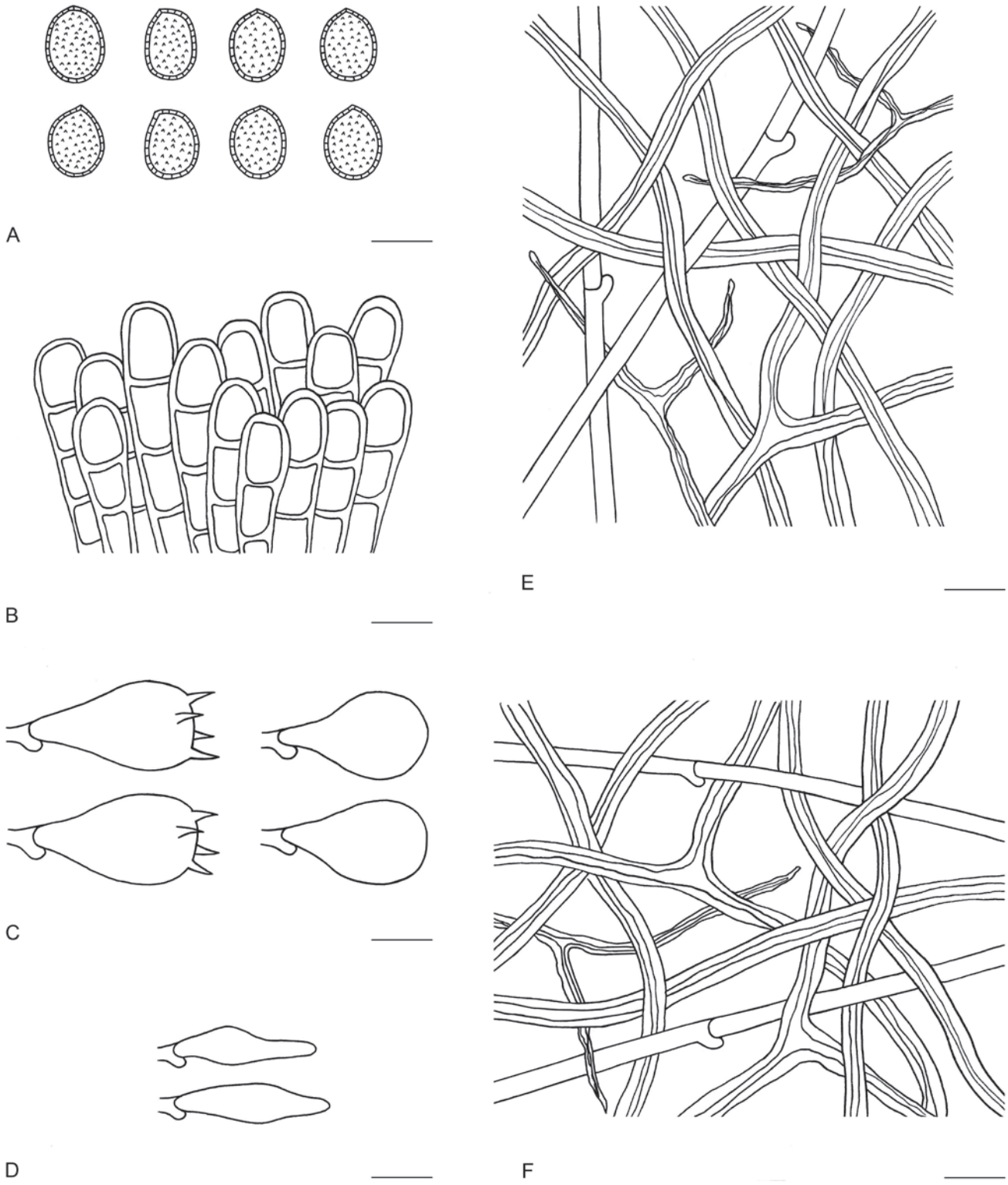

Fig. 70. Microscopic structures of *Sanguinoderma longistipitum* (drawn from Dai 20696). **A.** Basidiospores. **B.** Apical cells from cuticle. **C.** Basidia and basidioles. **D.** Cystidioles. **E.** Hyphae from trama. **F.** Hyphae from context. Scale bars = 10 µm.

Sanguinoderma melanocarpum B.K. Cui & Y.F. Sun, ***sp. nov.*** MycoBank MB 839667. Figs 71, 72.

Diagnosis: Differs from other species in the genus by its small and sub-orbicular pilei, coal black pileal surface with alternating dark to light concentric furrows and strong radial wrinkles.

Etymology: *melanocarpum* (*Lat.*), refers to the coal black pileal surface.

Typus: **Malaysia**, Selangor, Kota Damansara, Community Forest Reserve, on ground, 16 Apr. 2018, Dai 18603 (**holotype** BJFC026891).

Additional material examined: **Malaysia**, Selangor, Taman Botani Negara Shah Alam, on stump of angiosperm tree, 12 Apr. 2018, Dai 18512 (BJFC026801).

Description: *Basidiomata* annual, laterally stipitate, hard corky to woody hard. *Pilei* solitary, sub-orbicular to flabelliform, up to 4.5

cm diam and 5 mm thick. *Pileal surface* coal black when fresh, dull, glabrous, with alternating dark to light concentric furrows and strong radial wrinkles, centre navel-shaped; margin obtuse, entire, wavy and incurved when dry. *Pore surface* cream to greyish white when fresh becoming to blood red when bruised and then quickly darkening; pores circular to angular, 6–8 per mm; dissepiments distinctly thick, entire. *Context* straw yellow to yellowish brown, with dark melanoid lines, hard corky, up to 3 mm thick. *Tubes* greyish brown to dark grey, up to 3 mm long. *Stipe* concolorous with pileal surface, cylindrical and hollow, slightly swollen at base, up to 12 cm long and 5 mm diam. *Hyphal system* trimitic; generative hyphae with clamp connections, all the hyphae IKI + (slightly dextrinoid), CB +; tissues darkening in KOH. Generative hyphae in context colourless, thin-walled, 3–5 µm diam; skeletal hyphae in context pale yellow, thick-walled with a wide to narrow lumen or sub-solid, arboriform and flexuous, 3–7 µm diam; binding hyphae in context colourless, sub-solid, branched and flexuous, 1–1.5 µm diam. Generative hyphae in tubes colourless, thin-walled, 3–4 µm diam; skeletal hyphae in tubes pale yellow, thick-walled with a wide to narrow lumen or sub-solid, slightly arboriform and flexuous, 3–6 µm diam; binding hyphae in tubes colourless, sub-solid, branched and flexuous, up to 1.5 µm diam. *Pileipellis* composed of clamped generative hyphae, thick-walled to sub-solid, apical cells clavate, faintly constricted and flexuous, yellowish brown, about 28–32 × 5–7 µm, forming a regular palisade. *Cystidia* and *cystidioles* absent. *Basidia* barrel-shaped, colourless, thin-walled, 20–25 × 12–17 µm; *basidioles* clavate, colourless, thin-walled, 16–22 × 10–16 µm. *Basidiospores* subglobose to broadly ellipsoid, pale yellow, IKI + (slightly dextrinoid), CB +, double-walled with slightly thick walls, exospore wall smooth, endospore wall with dense spinules, (10–)10.4–11.8(–12) × (8.8–)9–10.5(–10.8) µm, L = 10.98 µm, W = 9.77 µm, Q = 1.10–1.15 (n = 60/2).

Notes: *Sanguinoderma melanocarpum* was collected from Malaysia and it has sub-orbicular pilei, a dark pileal surface with strongly concentric furrows and radial wrinkles which are similar to *Sa. rugosum*, but *Sa. rugosum* differs from *Sa. melanocarpum* by dark brown pilei, slightly thick dissepiments of pores, clavate cystidioles and elliptical basidiospores (10.2–11.3 × 8.3–9.2 µm) without amyloid or dextrinoid reaction (Sun *et al.* 2020).

Fig. 71. Basidiomata of *Sanguinoderma melanocarpum*.

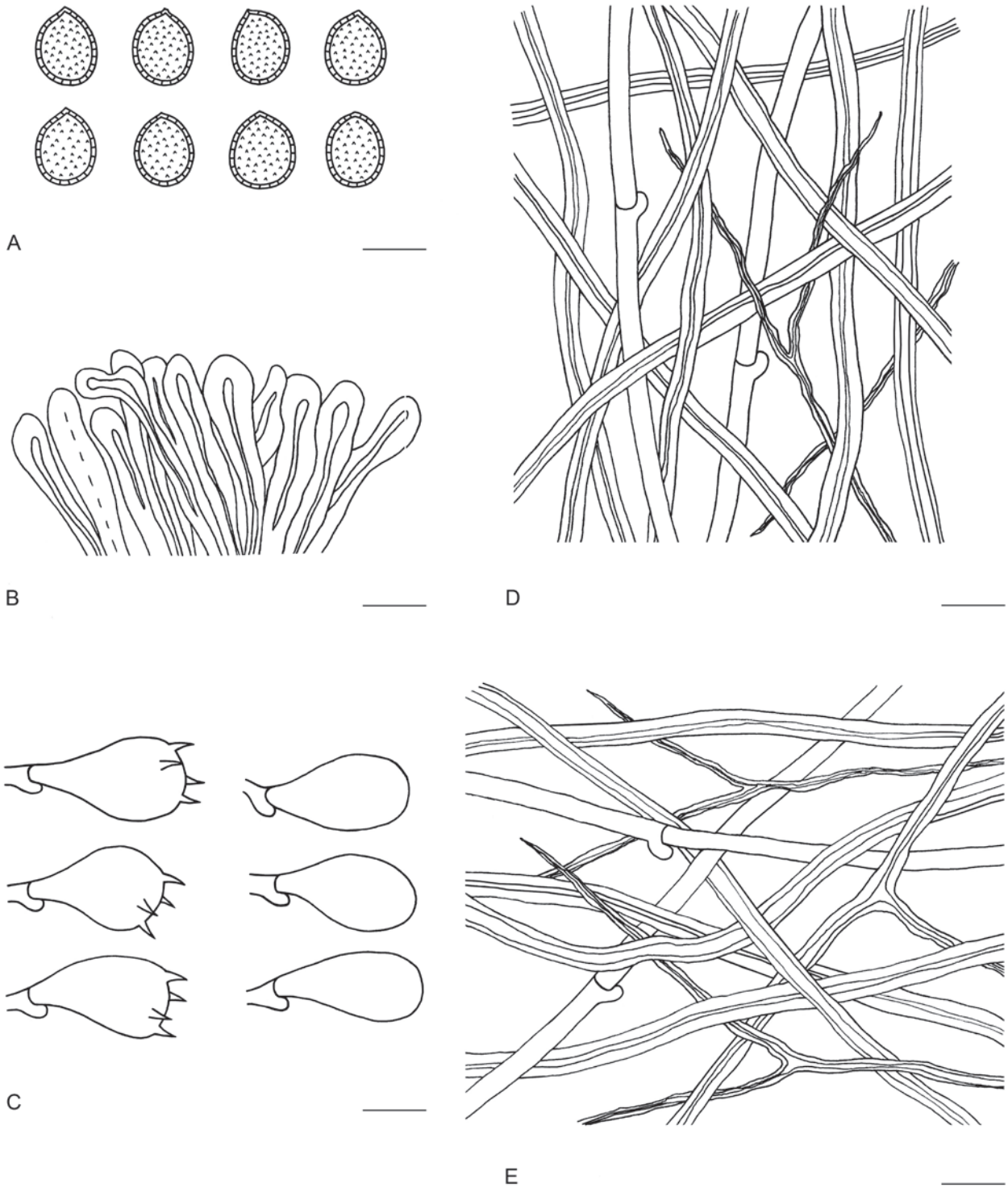

Fig. 72. Microscopic structures of *Sanguinoderma melanocarpum* (drawn from Dai 18603). **A.** Basidiospores. **B.** Apical cells from cuticle. **C.** Basidia and basidioles. **D.** Hyphae from trama. **E.** Hyphae from context. Scale bars = 10 µm.

Sanguinoderma microsporum B.K. Cui & Y.F. Sun, ***sp. nov.*** MycoBank MB 839668. Figs 73, 74.

Diagnosis: Differs from other species in the genus by having the smallest basidiospores.

Etymology: *microsporum* (*Lat.*), refers to the small basidiospores.

Typus: **Thailand**, Chiang Mai, Doi Saket, on ground, 24 Jul. 2016, Dai 16726 (**holotype** BJFC022833).

Additional materials examined: **China**, Hainan, Ledong County, Jianfengling Nature Reserve, on ground of angiosperm forest, 19 Jun. 2016, Cui 13897 (BJFC028763), Cui 13901 (BJFC028767).

Description: *Basidiomata* annual, centrally to laterally stipitate, hard corky. *Pilei* solitary, near orbicular, up to 4.5 cm diam and 3 mm thick. *Pileal surface* dark yellowish brown to almost black, dull, glabrous, with concentric zones and radial wrinkles; margin acute to obtuse, entire, incurved when dry. *Pore surface* pale yellowish brown to pale grey when dry, becoming to blood red when bruised

Fig. 73. Basidiomata of *Sanguinoderma microsporum*.

and then quickly darkening; pores circular to angular, 5–7 per mm; dissepiments slightly thick, entire. *Context* straw yellow, without dark melanoid lines, corky, up to 2 mm thick. *Tubes* pale straw yellow, up to 1 mm long. *Stipe* concolorous with pileal surface, cylindrical and hollow, up to 11 cm long and 7 mm diam. *Hyphal system* trimitic; generative hyphae with clamp connections, all hyphae IKI –, CB +; tissues darkening in KOH. Generative hyphae in context colourless, thin-walled, 3–5 µm diam; skeletal hyphae in context yellowish brown, thick-walled with a wide to narrow lumen or sub-solid, arboriform and flexuous, 4–7 µm diam; binding hyphae in context colourless, sub-solid, branched and flexuous, 1–2 µm diam. Generative hyphae in tubes colourless, thin-walled, 3–4 µm diam; skeletal hyphae in tubes pale yellow, thick-walled with a wide to narrow lumen or sub-solid, arboriform and flexuous, 3–6 µm diam; binding hyphae in tubes colourless, sub-solid, branched and flexuous, up to 1.5 µm diam. *Pileipellis* composed of clamped generative hyphae, slightly thick-walled, apical cells clavate, slightly inflated, reddish brown, about 30–40 × 5–8 µm, forming a regular palisade. *Cystidia* and *cystidioles* absent. *Basidia* clavate, colourless, thin-walled, 14–23 × 9–11 µm; *basidioles* in shape like the basidia, colourless, thin-walled, 12–17 × 5–10 µm. *Basidiospores* subglobose to broadly ellipsoid, pale brown, IKI –, CB +, double-walled with slightly thick walls, exospore wall smooth, endospore wall with dense spinules, (4.3–)4.7–5.6(–5.9) × (4–)4.3–5.2(–5.4) µm, L = 5.22 µm, W = 4.79 µm, Q = 1.06–1.12 (n = 60/2).

Notes: *Sanguinoderma microsporum* is unique in the genus due to its small basidiospores. It is like *Sa. melanocarpum* in the almost black orbicular pilei with long stipe, but the latter can be distinguished by smaller pores (6–8 per mm) with distinctly thick dissepiments, harder context with dark melanoid lines, and larger basidiospores (10.4–11.8 × 9.0–10.5 µm) with slightly dextrinoid reaction.

Sanguinoderma tricolor B.K. Cui & Y.F. Sun, ***sp. nov.*** MycoBank MB 839669. Figs 75, 76.

Diagnosis: Differs from other species in the genus by its hard basidiomata with concentric zonate pileal surface in three different colours when fresh.

Etymology: *tricolor* (*Lat.*), refers to the pileal surface with obvious concentric zones in three different colours.

Typus: **Malaysia**, Selangor, Kota Damansara, National Forest Reserve, on ground, 7 Dec. 2019, Cui 18292 (**holotype** BJFC035151).

Additional materials examined: **Malaysia**, Selangor, Kota Damansara, National Forest Reserve, on ground, 6 Dec. 2019, Cui 18242 (BJFC035101); Forest Research Institute of Malaysia, on stump of *Hopea*, 15 Apr. 2018, Dai 18574 (BJFC026862).

Description: *Basidiomata* annual, laterally stipitate, hard corky to woody hard. *Pilei* solitary, flabelliform to reniform, up to 12 cm diam and 1 cm thick. *Pileal surface* rust colour, dark brown to almost black when fresh, dull, glabrous, with obvious concentric zones in different colours and radial wrinkles; margin obtuse, entire, very

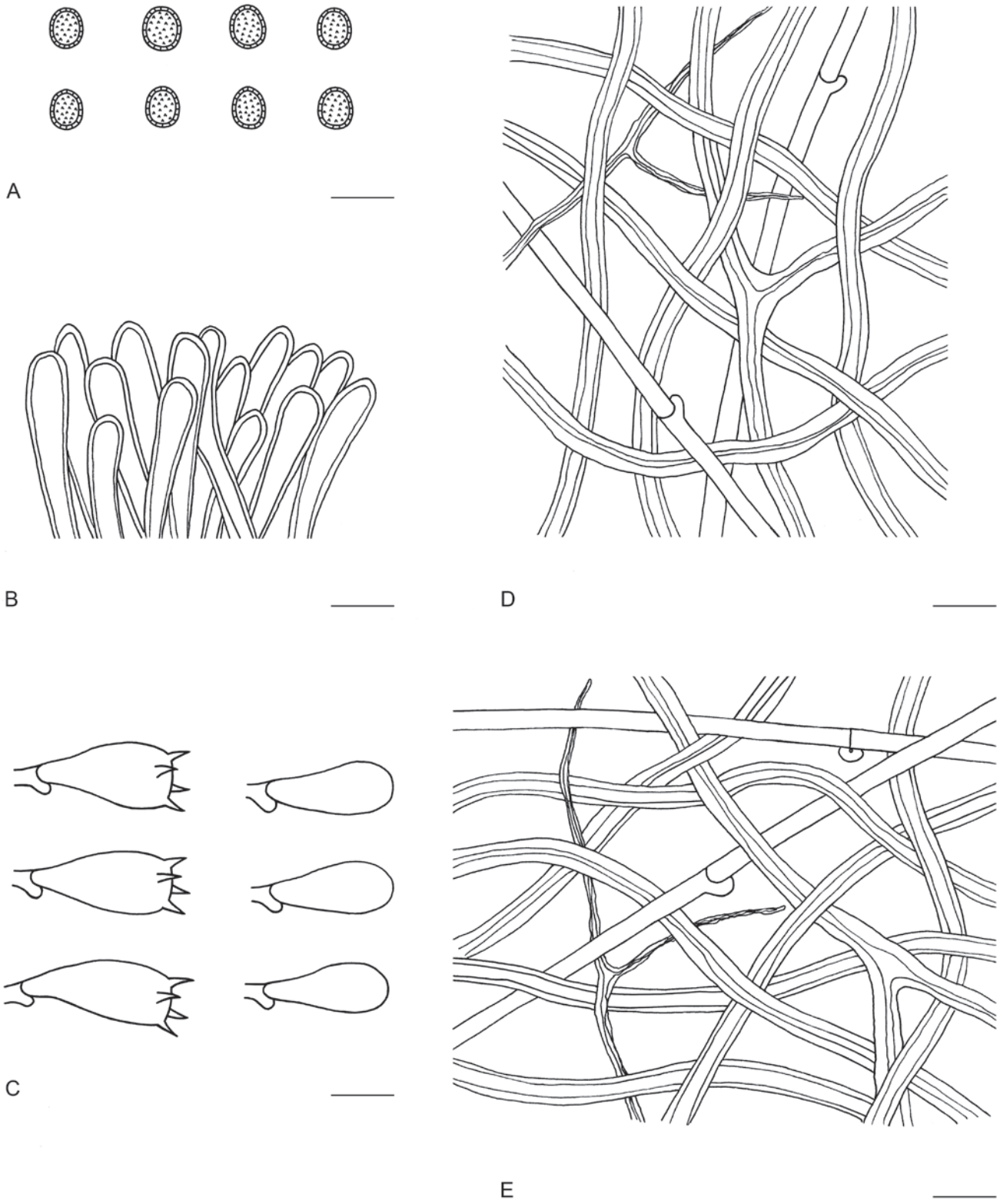

Fig. 74. Microscopic structures of *Sanguinoderma microsporum* (drawn from Dai 16726). **A.** Basidiospores. **B.** Apical cells from cuticle. **C.** Basidia and basidioles. **D.** Hyphae from trama. **E.** Hyphae from context. Scale bars = 10 µm.

wavy and incurved when dry. *Pore surface* cream to yellowish brown when fresh becoming to blood red when bruised and then quickly darkening, or unchanging in old specimens; pores circular, 5–7 per mm; dissepiments extremely thick (about 0.11–0.14 mm thick), entire. *Context* pale straw yellow to wood brown, without dark melanoid lines, hard corky, up to 3 mm thick. *Tubes* dark straw yellow to pale brown, up to 8 mm long. *Stipe* concolourous with pileal surface, cylindrical and solid, swollen at base, up to 5.5 cm long and 1.5 cm diam. *Hyphal system* trimitic; generative hyphae with clamp connections, all hyphae IKI –, CB +; tissues darkening in KOH. Generative hyphae in context colourless, thin-walled, 3–4 µm diam; skeletal hyphae in context pale golden yellow, thick-walled with a wide to narrow lumen or sub-solid, arboriform and flexuous, 3–7 µm diam; binding hyphae in context colourless, sub-solid, branched and flexuous, 1–2 µm diam. Generative hyphae in tubes colourless, thin-walled, 3–5 µm diam; skeletal hyphae

Fig. 75. Basidiomata of *Sanguinoderma tricolor*.

in tubes pale yellowish brown, thick-walled with a wide to narrow lumen or sub-solid, arboriform and flexuous, 3–6 µm diam; binding hyphae in tubes colourless, sub-solid, branched and flexuous, up to 2 µm diam. *Pileipellis* composed of clamped generative hyphae, thick-walled to sub-solid, apical cells clavate, inflated and flexuous, yellowish brown, about 18–27 × 5–7 µm, forming a regular palisade. *Cystidia* and *cystidioles* absent. *Basidia* barrel-shaped to clavate, colourless, thin-walled, 15–25 × 10–15 µm; *basidioles* in shape like the basidia, colourless, thin-walled, 14–17 × 9–13 µm. *Basidiospores* subglobose to broadly ellipsoid, pale yellow, IKI –, CB +, double-walled with slightly thick walls, exospore wall smooth, endospore wall with dense spinules, (10–)10.2–11.5(–12) × (8.3–)8.8–10.2(–10.5) µm, L = 10.91 µm, W = 9.53 µm, Q = 1.13–1.16 (n = 60/2).

Notes: *Sanguinoderma tricolor* is a distinct species on account of its pileal surface with concentric zones in three different colours when fresh. It can be confused with *Sa. microporum* by having hard basidiomata, and small pores (5–7 per mm) with extremely thick dissepiments (about 0.12–0.16 mm thick), but *Sa. microporum* differs from *Sa. tricolor* by the monochromatic pileal surface, context with dark melanoid lines, larger and more elliptical basidiospores (11–12 × 8.7–9.8 µm, Q = 1.23–1.28, Sun *et al.* 2020).

Key to accepted species of *Sanguinoderma*

1a. Pore dissepiments extremely thick 2
1b. Pore dissepiments thin to distinctly thick 3

2a. Pileal surface pale yellowish brown, pore surface yellowish brown, context with dark melanoid lines ..... *Sa. microporum*
2b. Pileal surface rust brown to almost black, pore surface white to pale yellow, context without dark melanoid lines ..... *Sa. tricolor*

3a. Pore dissepiments lacerate, tubes fascicular when dry ..... *Sa. laceratum*
3b. Pore dissepiments entire, tubes unchanged when dry 4

4a. Pores ≤ 4 per mm 5
4b. Pores > 4 per mm 7

5a. Pores sinuate; basidiospores > 13.5 µm in length ..... *Sa. sinuosum*
5b. Pores circular to irregular; basidiospores < 13.5 µm in length 6

6a. Pore dissepiments thin; basidiospores globose to subglobose ..... *Sa. bataanense*
6b. Pore dissepiments slightly thick; basidiospores subglobose to broadly ellipsoid ..... *Sa. rude*

7a. Basidiospores < 6 µm in length ..... *Sa. microsporum*
7b. Basidiospores > 6 µm in length 8

8a. Pileal surface coal black; basidiospores slightly dextrinoid in Melzer's reagent ..... *Sa. melanocarpum*
8b. Pileal surface brown to almost black; basidiospores IKI– in Melzer's reagent 9

9a. Pileipellis composed of apical cells with obvious septa 10
9b. Pileipellis composed of apical cells without obvious septa 12

10a. Basidiomata with long stipe; apical cells of pileipellis digitate, with multiple septa ..... *Sa. longistipitum*
10b. Basidiomata with short stipe; apical cells of pileipellis clavate, with simple septa 11

11a. Pilei applanate, reniform, pileal surface dark brown to almost black ..... *Sa. elmerianum*
11b. Pilei funnel-shape, pileal surface yellowish brown to greyish brown ..... *Sa. infundibulare*

12a. Cystidioles absent 13
12b. Cystidioles present 14

13a. Pore surface yellowish green when fresh; basidiospores subglobose to broadly ellipsoid ..... *Sa. flavovirens*
13b. Pore surface pale grey when fresh; basidiospores reniform ..... *Sa. reniforme*

14a. Basidiomata sessile to subsessile; basidiospores ≥ 14 µm in length ..... *Sa. perplexum*
14b. Basidiomata stipitate; basidiospores < 14 µm in length 15

15a. Pileal surface with shades of brown concentric zones and slender radial lines, context fibrous ..... *Sa. guangdongense*
15b. Pileal surface with concentric furrows and radial wrinkles, context corky ..... *Sa. rugosum*

Sinoganoderma B.K. Cui, J.H. Xing & Y.F. Sun, ***gen. nov.*** MycoBank MB 839661.

Diagnosis: Differs from other genera by its ganodermoid basidiomata, applanate pilei with pale yellow pileal surface, cream context, thin dissepiments of pores, truncated basidiospores with an uneven or foveolate exospore wall and solid spinules on the endospore wall.

Etymology: *sinoganoderma* (*Lat.*), refers to the genus producing ganoderma-like basidiomata and distributed in China.

Type species: *Sinoganoderma shandongense* (J.D. Zhao & L.W. Xu) B.K. Cui *et al*.

Description: *Basidiomata* annual, stipitate, corky. *Pilei* solitary, flabelliform to shell-shaped, applanate. *Pileal surface* pale yellow to reddish brown, slightly laccate, glabrous, with concentric furrows and radial wrinkles. *Pore surface* near white when fresh; pores circular; dissepiments thin, entire. *Context* cream to pale wood brown, without dark melanoid lines, soft corky. *Hyphal system* trimitic; generative hyphae colourless, thin-walled, with clamp connections; skeletal hyphae near colourless to pale yellow, with narrow lumen or sub-solid, arboriform and flexuous; binding hyphae colourless, thick-walled, branched and flexuous. *Basidiospores* ellipsoid to ovoid, truncated, pale yellowish brown, double-walled and distinctly thick-walled, exospore wall uneven or foveolate, endospore wall with solid spinules.

Notes: *Sinoganoderma* is established due to its pale yellow pileal surface, cream context, thin dissepiments of pores, and truncated basidiospores with an uneven or foveolate exospore wall and solid spinules on the endospore wall. It is composed of one species which has been only collected from China. The ornamentation of the exospore wall of basidiospores observed under SEM is similar to *Foraminispora*, but the hollow and columnar spinules which persist until the exospore wall forming visible holes make *Foraminispora* different from other genera in *Ganodermataceae*. In the phylogenetic analyses, *Sinoganoderma* formed an independent clade distinct from other genera within *Ganodermataceae* and, so far, is monotypic (Fig. 1).

Sinoganoderma shandongense (J.D. Zhao & L.W. Xu) B.K. Cui, J.H. Xing & Y.F. Sun, ***comb. nov.*** MycoBank MB 839662. Figs 77, 78.
Basionym: *Ganoderma shandongense* J.D. Zhao & L.W. Xu, Acta Mycol. Sin. 5: 90. 1986.

Description: *Basidiomata* annual, laterally stipitate, corky. *Pilei* solitary, flabelliform to shell-shaped, applanate, up to 6.5 cm diam and 2.5 mm thick. *Pileal surface* pale yellow to reddish brown, slightly laccate, glabrous, with concentric furrows and radial wrinkles; margin obtuse, entire. *Pore surface* near white when fresh; pores circular, 3–5 per mm; dissepiments thin, entire. *Context* cream to pale wood brown, without dark melanoid lines, soft corky, up to 6 mm thick. *Tubes* cream, up to 4.3 mm long. *Stipe* purplish-red, slightly laccate, cylindrical and solid, slightly

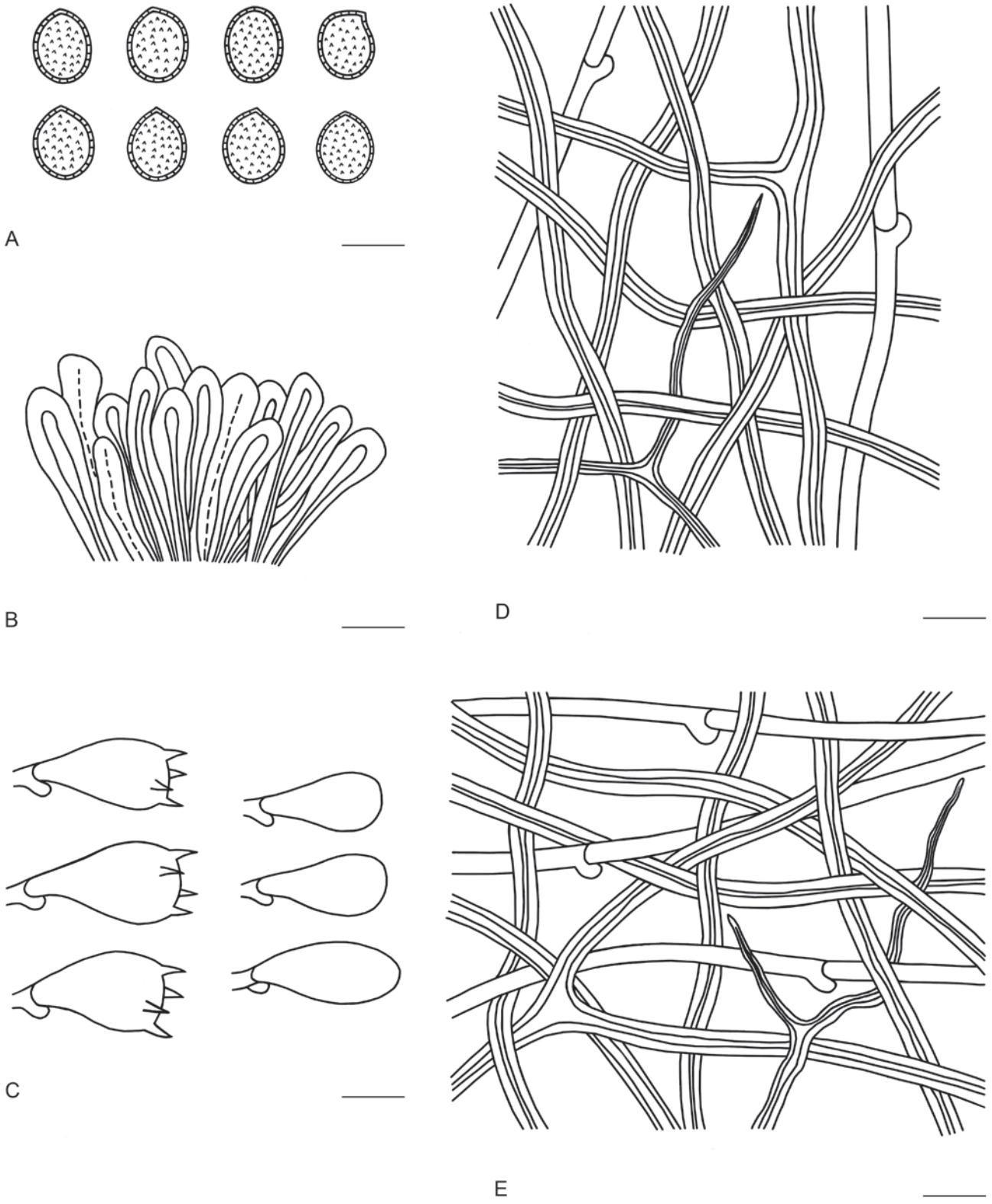

Fig. 76. Microscopic structures of *Sanguinoderma tricolor* (drawn from Cui 18292). **A.** Basidiospores. **B.** Apical cells from cuticle. **C.** Basidia and basidioles. **D.** Hyphae from trama. **E.** Hyphae from context. Scale bars = 10 μm.

swollen at base, up to 5.6 cm long and 1.2 cm diam. *Hyphal system* trimitic; generative hyphae with clamp connections, all hyphae IKI –, CB +; tissues slightly darkening in KOH. Generative hyphae in context colourless, thin-walled, 2–4 μm diam; skeletal hyphae in context near colourless to pale yellow, with narrow lumen or sub-solid, arboriform and flexuous, 2–5 μm diam; binding hyphae in context colourless, thick-walled, branched and flexuous, 1–2 diam. Generative hyphae in tubes colourless, thin-walled, 3–4 μm diam; skeletal hyphae in tubes near colourless, almost sub-solid, arboriform and flexuous, 2–4 μm diam; binding hyphae in tubes colourless, thick-walled, branched and flexuous, up to 1.5 μm diam. *Pileipellis* composed of clamped generative hyphae, thick-walled, apical cells clavate, inflated and flexuous, pale yellowish brown, about 37–45 × 5–9 μm, forming a regular palisade. *Cystidia* and *cystidioles* absent. *Basidia* barrel-shaped to clavate, colourless, thin-walled, 13–19 × 10–18 μm; *basidioles* in shape like the basidia,

Fig. 77. Basidiomata of *Sinoganoderma shandongense*.

colourless, thin-walled, 12–16 × 8–10 µm. *Basidiospores* ellipsoid to ovoid, truncated, pale yellowish brown, IKI –, CB +, double-walled with distinctly thick walls, exospore wall uneven or foveolate, endospore wall with solid spinules, (11.9–)12–13.2(–13.3) × (7.8–)8–9(–9.2) µm, L = 12.66 µm, W = 8.42 µm, Q = 1.49–1.52 (n = 60/2, with the turgid vesicular appendix included).

Materials examined: **China**, Shandong, Changqing County, Liantaishan Forest Park, on stump of *Albizia*, 24 Aug. 2015, Dai 15785 (BJFC019889), Dai 15786 (BJFC019890); on living tree of *Albizia*, 24 Aug. 2015, Dai 15787 (BJFC019891), Dai 15788 (BJFC019892), Dai 15790 (BJFC019894), Dai 15791 (BJFC019895); on living tree of *Albizia*, 6 Aug. 2019, Dai 20243 (BJFC031911), Dai 20244 (BJFC031912).

Notes: *Sinoganoderma shandongense* was firstly described by Zhao & Zhang (1986a) as *Ganoderma shandongense*. It has typical ganodermoid morphology, but *Si. shandongense* formed an independent lineage in the phylogenetic analyses (Fig. 1). It is worth mentioning that the sequences of two specimens (xsd08032 and xsd08085) uploaded into GenBank as *G. ramosissimum* are identical with *Si. shandongense* based on phylogenetic results in this study, and therefore the name of the two specimens (xsd08032 and xsd08085) needs to change to *Si. shandongense.*

Tomophagus Murrill, Torreya 5: 197. 1905. MycoBank MB 18657.

Type species: *Tomophagus colossus* (Fr.) Murrill

Description: *Basidiomata* annual, sessile, soft corky. *Pilei* solitary, flabelliform. *Pileal surface* pale straw yellow to reddish brown, slightly laccate, glabrous, without ornamentation or not obvious. *Pore surface* white to straw yellow; pores circular; dissepiments thick, entire. *Context* white to wood brown, soft corky. *Hyphal system* dimitic; generative hyphae colourless, thin-walled, branched, with clamp connections; skeletal hyphae colourless to pale yellow, thick-walled, thick-walled with narrow lumen or sub-solid, arboriform, strongly collapsed and flexuous. *Basidiospores* ellipsoid to ovoid, truncated, yellow to pale yellowish brown, double-walled with distinctly thick walls, exospore wall slightly foveolate to verrucose or reticulate, endospore wall with short and irregular ridges.

Notes: *Tomophagus* has typical ganodermoid basidiospores, but its pale white and soft context make it different from other genera (Murrill 1905, Le *et al.* 2012). Two species, *To. colossus* and *To. cattienensis* are accepted in *Tomophagus*. In the phylogenetic analyses, *Tomophagus* formed an independent clade within *Ganodermataceae* (Fig. 1).

Tomophagus cattienensis X.T. Le & Moncalvo, Mycol. Prog. 11: 777. 2012. MycoBank MB 561806. Figs 79, 80.

Description: *Basidiomata* annual, sessile, soft corky. *Pilei* solitary, flabelliform, up to 8 cm diam and 3 cm thick. *Pileal surface* pale straw yellow when fresh, slightly laccate, glabrous, without ornamentation;

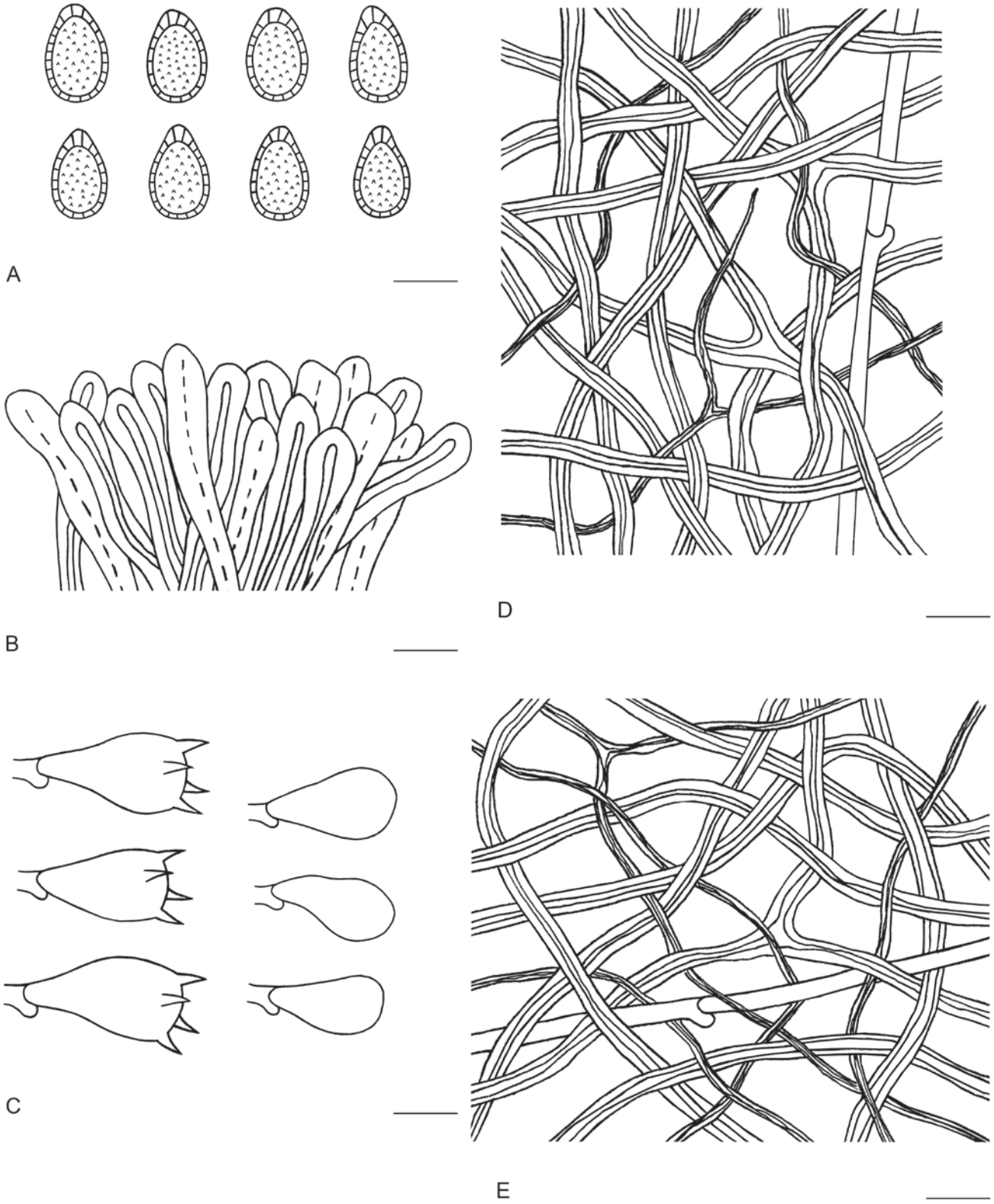

Fig. 78. Microscopic structures of *Sinoganoderma shandongense* (drawn from Dai 20244). **A.** Basidiospores. **B.** Apical cells from cuticle. **C.** Basidia and basidioles. **D.** Hyphae from trama. **E.** Hyphae from context. Scale bars = 10 μm.

margin obtuse, entire, and incurved when dry. *Pore surface* pale wood brown to straw yellow becoming dark when bruised; pores circular to oval, 3–5 per mm; dissepiments moderately thick, entire. *Context* wood brown, with dark resinous lines, soft corky, slightly fibrous and powdery, up to 3 cm thick. *Tubes* pale greyish brown, corky, up to 5 mm long. Hyphal system dimitic; generative hyphae with clamp connections, all hyphae IKI –, CB +; tissues darkening in KOH. Generative hyphae in context colourless, thin-walled, branched, 3–4 μm diam; skeletal hyphae in context pale yellow, thick-walled with narrow lumen or sub-solid, arboriform, strongly collapsed and flexuous, 3–5 μm diam. Generative hyphae in tubes colourless, thin-walled, branched, 3–4 μm diam; skeletal hyphae in tubes colourless to pale yellow, thick-walled with narrow lumen or sub-solid, arboriform, strongly collapsed and flexuous, 3–4 μm diam. *Pileipellis* composed of clamped generative hyphae, thin- to slightly thick-walled, apical cells clavate, faintly inflated,

Fig. 79. Basidiomata of *Tomophagus cattienensis*.

colourless to pale yellow, about 32–45 × 4–7 µm, forming a regular palisade. *Cystidia* and *cystidioles* absent. *Basidia* barrel-shaped to clavate, colourless, thin-walled, 18–27 × 10–13 µm; *basidioles* in shape like the basidia, colourless, thin-walled, 15–20 × 9–12 µm. *Basidiospores* ellipsoid to ovoid, truncated, pale yellowish brown, IKI –, CB +, double-walled with distinctly thick walls, exospore wall slightly foveolate, endospore wall with short and irregular ridges, (10–)10.2–11.8(–11.9) × (6.3–)6.5–7.8(–8) µm, L = 11.09 µm, W = 7.22 µm, Q = 1.54 (n = 60/1, with the turgid vesicular appendix excluded); (11.2–)11.3–12.7(–13) × (6.8–)7–8(–8.2) µm, L = 12.04 µm, W = 7.39 µm, Q = 1.63 (n = 60/1, with the turgid vesicular appendix included).

Material examined: **Malaysia**, Selangor, Jeram, on dead tree of *Elaeis*, 10 Apr. 2018, Dai 18487 (BJFC026776).

Notes: *Tomophagus cattienensis* was described from South Vietnam, and it can be distinguished from *To. colossus* by its pale red-brown and laccate pileal surface, pale brown context when dry, and slightly larger basidiospores (17.5–21.5 × 11.5–14.5 µm, Le *et al.* 2012). The specimen of *To. cattienensis* used in this study was collected from Malaysia, and it grouped with another *To. cattienensis* specimen in the phylogenetic analyses (Fig. 1). However, the specimens used in Le *et al.* (2012) showed different morphological characters to our specimen, such as a reddish brown pileal surface, larger pores (2–3 per mm), and larger basidiospores (17.5–21.5 × 11.5–14.5 µm).

Key to accepted species of *Tomophagus*

1a. Pileal surface reddish brown; basidiospores smaller (10.2–11.8 × 6.5–7.8 µm) ..... *To. cattienensis*
1b. Pileal surface yellow; basidiospores larger (14–20 × 9–14 µm) ..... *To. colossus*

Trachydermella B.K. Cui & Y.F. Sun, ***gen. nov.*** MycoBank MB 840976.

Diagnosis: Differs from other genera by its sessile basidiomata with flatly flabelliform pilei, trachytic and ochraceous to yellowish brown pileal surface, watery context.

Etymology: *trachydermella* (*Lat.*), refers to the genus having trachytic pileal surface.

Type species: *Trachydermella tsunodae* (Yasuda ex Lloyd) B.K. Cui & Y.F. Sun

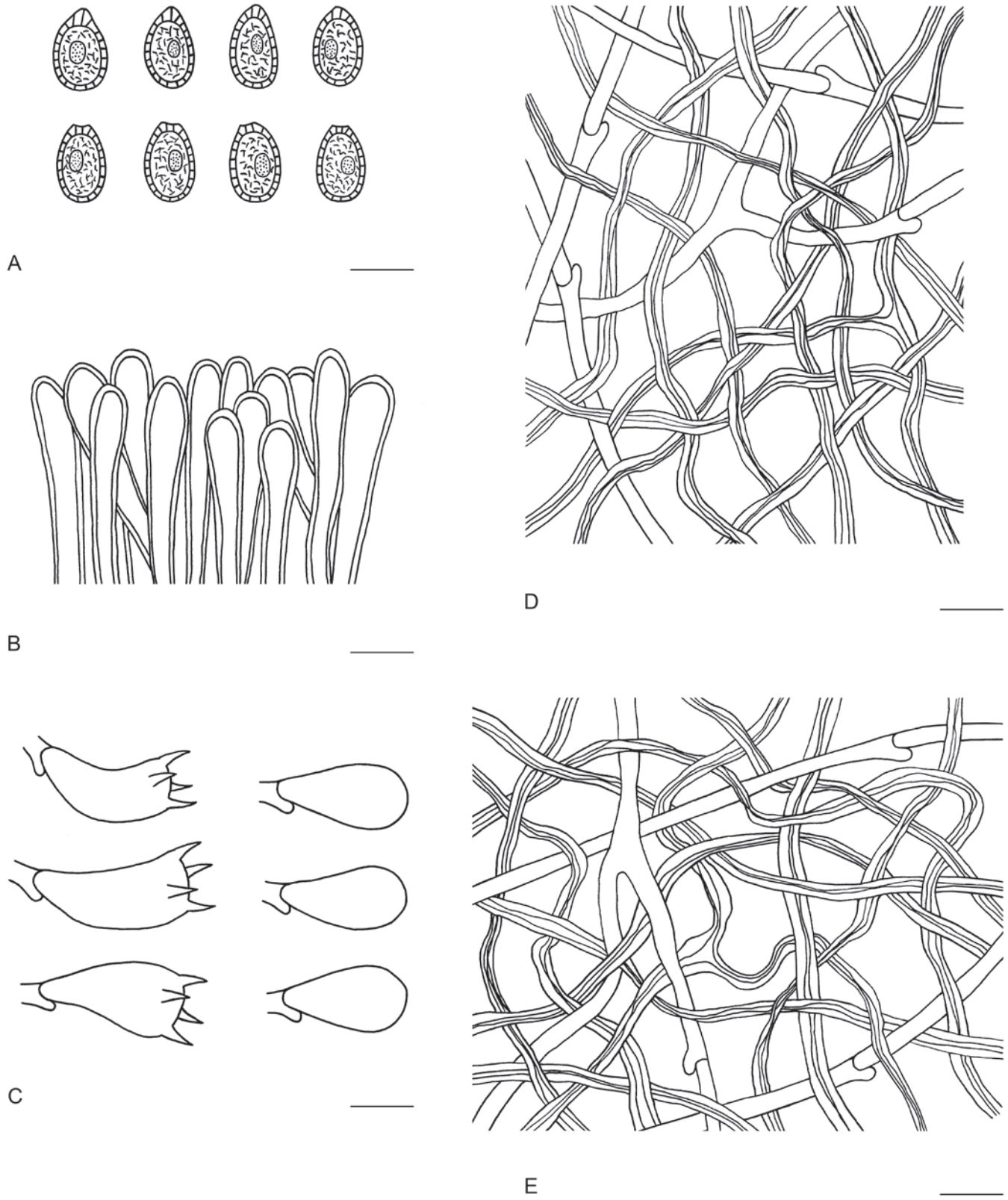

Fig. 80. Microscopic structures of *Tomophagus cattienensis* (drawn from Dai 18487). **A.** Basidiospores. **B.** Apical cells from cuticle. **C.** Basidia and basidioles. **D.** Hyphae from trama. **E.** Hyphae from context. Scale bars = 10 μm.

Description: *Basidiomata* annual, sessile, soft when fresh. *Pilei* solitary, flatly flabelliform. *Pileal surface* ochraceous to yellowish brown when fresh, dull, glabrous, trachytic, with concentric zones and radial wrinkles. *Pore surface* wood brown when dry; pores circular; dissepiments thick, entire. *Context* cream, watery when fresh and turning hard corky when dry. *Hyphal system* trimitic; generative hyphae colourless, thin-walled, with clamp connections; skeletal hyphae pale yellow, thick-walled with narrow lumen or sub-solid, arboriform and flexuous; binding hyphae colourless, thick-walled, rarely branched and flexuous. *Basidiospores* ellipsoid to ovoid, truncated, pale yellow, double-walled with distinctly thick walls, exospore wall verrucose to vermicular, endospore wall with conspicuous spinules.

Notes: *Trachyderma* is an illegitimate name as homonym of a lichen genus in *Pannariaceae* and was renamed as *Trachydermella*

in this study. *Trachydermella* is similar to *Tomophagus* in the pale white and soft context when fresh, but pale straw yellow pilei with non-obvious ornamentation, dimitic hyphal system with branched generative hyphae, and smaller basidiospores of *Tomophagus* can distinguish them easily (Murrill 1905, Le *et al.* 2012). In the phylogenetic analyses, *Trachydermella* formed an independent clade within *Ganodermataceae* (Fig. 1).

Trachydermella tsunodae (Yasuda ex Lloyd) B.K. Cui & Y.F. Sun, ***comb. nov.*** MycoBank MB 306952. Figs 81, 82.
Basionym: *Polyporus tsunodae* Yasuda ex Lloyd, Mycol. Writ. (Cincinnati) 5: 792. 1918.

Description: *Basidiomata* annual, sessile, soft corky when fresh. *Pilei* solitary, flatly flabelliform, up to 8 cm diam and 3 mm thick. *Pileal surface* ochraceous to yellowish brown when fresh, dull, glabrous, with obvious dark concentric zones and radial wrinkles; margin obtuse, entire, incurved when dry. *Pore surface* wood brown when dry; pores circular, 3–5 per mm; dissepiments moderately thick, entire. *Context* cream to pale wood brown, with dark melanoid lines, watery when fresh and turning hard corky when dry, up to 1.5 mm thick. *Tubes* straw yellow, up to 1.2 mm long. *Hyphal system* trimitic; generative hyphae with clamp connections, all the hyphae IKI + (dextrinoid), CB +; tissues darkening in KOH. Generative hyphae in context colourless, thin-walled, 2–3 µm diam; skeletal hyphae in context pale yellow, thick-walled with narrow lumen or sub-solid, arboriform and flexuous, 2–5 µm diam; binding hyphae in context colourless, thick-walled, rarely branched and flexuous, 1–1.5 µm diam. Generative hyphae in tubes colourless, thin-walled, 2–3 µm diam; skeletal hyphae in tubes pale yellow, thick-walled with narrow lumen or sub-solid, arboriform and flexuous, 2–4 µm diam; binding hyphae in tubes colourless, thick-walled, rarely branched and flexuous, up to 1.5 µm diam. *Pileipellis* composed of clamped generative hyphae, thin- to slightly thick-walled, apical cells clavate, flexuous, yellowish brown, about 25–43 × 3–7 µm, forming a patchy palisade. *Cystidia* and *cystidioles* absent. *Basidia* barrel-shaped, colourless, thin-walled, 25–35 × 22–24 µm; *basidioles* in shape like the basidia, colourless, thin-walled, 20–27 × 12–20 µm. *Basidiospores* ellipsoid to ovoid, truncated, pale yellow, IKI + (dextrinoid), CB +, double-walled with distinctly thick walls, exospore wall verrucose to vermicular, endospore wall with conspicuous spinules, (19.4–)19.8–21.5(–22) × (12.5–)12.7–15(–15.2) µm, L = 20.48 µm, W = 13.96 µm, Q = 1.47 (n = 60/1, with the turgid vesicular appendix included).

Material examined: **China**, Guizhou, on dead tree of *Litsea cubeba*, 17 Jun. 2000, Dai 3221c (BJFC018543).

Notes: The holotype of *Trachydermella tsunodae* was collected from Japan, and is distinguished by its pale white and watery context when fresh, large basidia (25–35 × 22–24 µm) and basidioles (20–27 × 12–20 µm), and truncated basidiospores with verrucose to vermicular exospore walls. The specimens of *Tr. tsunodae* used in this study were collected from Guizhou Province in southwest China. Our observations of *Tr. tsunodae* are generally consistent with the original description, but the obvious binding hyphae observed in this specimen are contrary to the dimitic hyphal system recorded by Imazeki (1952).

Fig. 81. Basidiomata of *Trachydermella tsunodae*.

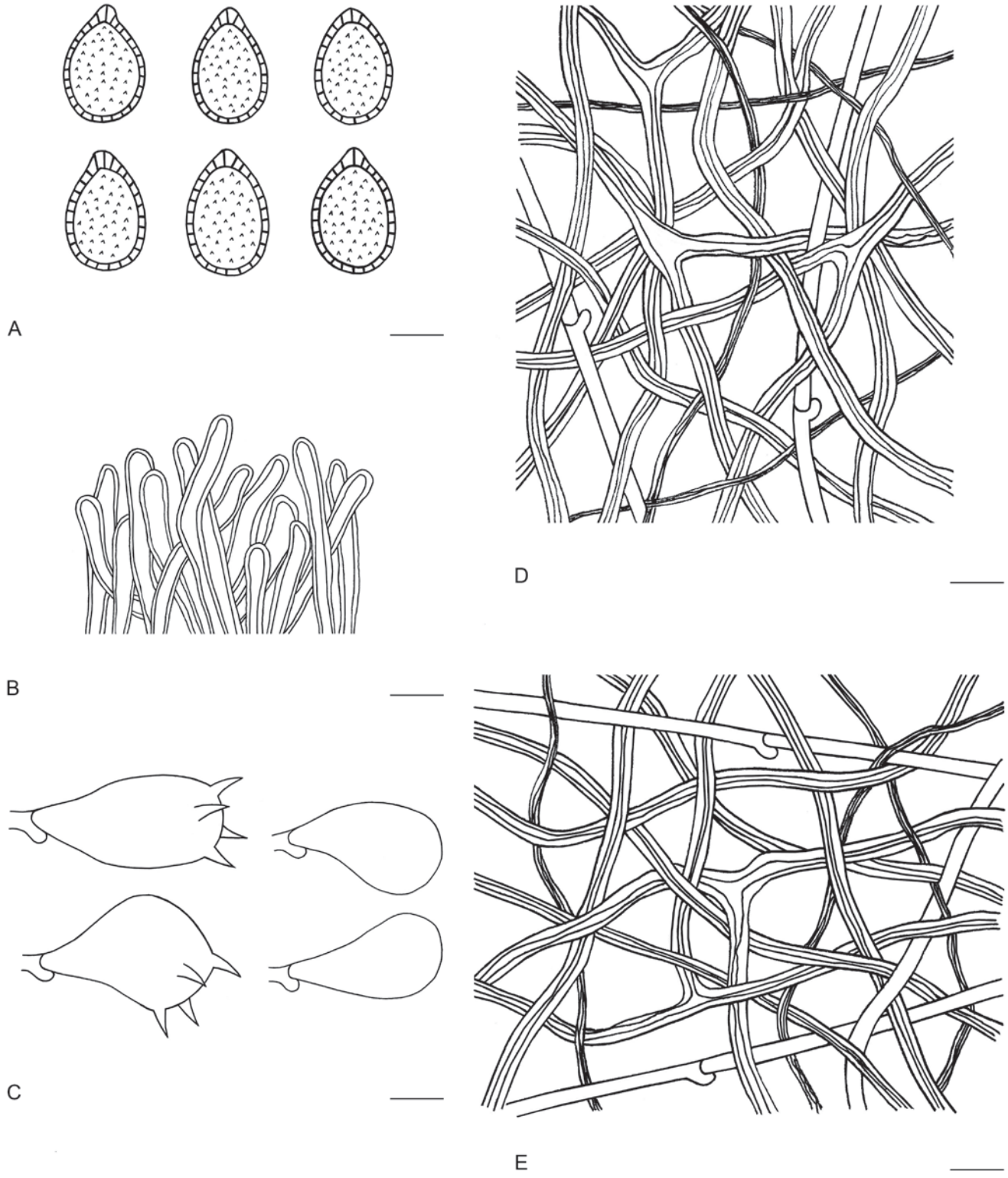

Fig. 82. Microscopic structures of *Trachyderma tsunodae* (drawn from Dai 3221c). **A.** Basidiospores. **B.** Apical cells from cuticle. **C.** Basidia and basidioles. **D.** Hyphae from trama. **E.** Hyphae from context. Scale bars = 10 μm.

DISCUSSION

Ganodermataceae is one of the most important families of macrofungi with many species having important ecological and economic values (Pilotti 2005, Dai *et al.* 2009, Glen *et al.* 2009, Cao *et al.* 2012, Chan *et al.* 2013, Zhou *et al.* 2015, Jong *et al.* 2017, Rodríguez-Couto 2017, Zhang *et al.* 2019, Wang *et al.* 2021). As species of the family have medicinal, agricultural and biotechnological application, accurate classification of *Ganodermataceae* has been pursued for a long time (Murrill 1905, Donk 1948, Imazeki 1952, Steyaert 1972, Moncalvo & Ryvarden 1997, Ryvarden 2004b, Costa-Rezende *et al.* 2017, 2020b, Sun *et al.* 2020). *Ganodermataceae* is a large and complex family and although many studies have focused on *Ganodermataceae*, the species diversity, geographic distribution, species classification, taxonomy and phylogeny of *Ganodermataceae* remained uncertain.

Donk (1948) proposed *Ganodermataceae* as a family, but it was not widely accepted until the sixth edition of the "Dictionary of Fungi" published by Ainsworth & Bisby (1971). Since then, *Ganodermataceae* has been treated as a family with unique

double-walled basidiospores with particular ornamentation on the endospore walls in the *Polyporales* (Ryvarden 2004b, Costa-Rezende *et al.* 2017, 2020b, Hapuarachchi *et al.* 2019b). Based on morphological observations and the six-gene combined phylogenetic analyses, 14 genera were confirmed in *Ganodermataceae*: *Amauroderma*, *Amaurodermellus*, *Cristataspora*, *Foraminispora*, *Furtadoella gen. nov.*, *Ganoderma*, *Haddowia*, *Humphreya*, *Magoderna*, *Neoganoderma gen. nov.*, *Sanguinoderma*, *Sinoganoderma gen. nov.*, *Tomophagus* and *Trachydermella gen. nov*. Besides the four new genera, detailed descriptions for *Ganoderma*, *Haddowia*, *Humphreya*, *Magoderna*, *Sanguinoderma* and *Tomophagus* are also provided in this study. The details of *Amauroderma*, *Amaurodermellus*, *Cristataspora*, *Foraminispora* and *Furtadoella gen. nov.* are well-presented in Costa-Rezende *et al.* (2017, 2020b) and Sun *et al.* (2020). In our work, SEM micrographs of basidiospores of 10 genera in *Ganodermataceae* were presented (Fig. 8). The keys for six genera of *Ganodermataceae* are provided, and 56 species including 23 new species are described and illustrated.

Neoganoderma was presented as a new genus with one species, *N. neurosporum*. The study of *N. neurosporum* is limited due to the scarcity of specimens from the Neotropics, and detailed description was provided by Ryvarden (2004b) and Costa-Rezende *et al.* (2020b). *Neoganoderma* can be distinguished by its unique basidiospores with longitudinal ridges which equal in length to basidiospores on the endospore wall.

Sinoganoderma has similar morphological characters with *Ganoderma*, such as flabelliform pilei with pale reddish brown and laccate pileal surface, truncated basidiospores with ornamentation on the endospore wall. However, *Sinoganoderma* differs by its applanate pilei with paler pileal surface, cream context, large pores with thin dissepiments, truncated basidiospores with an uneven or foveolate exospore wall and solid spinules on the endospore wall (Fig. 8 H). *Sinoganoderma shandongense* is the only species recognised in *Sinoganoderma*. It was originally described as *G. shandongense* from temperate areas of Shandong Province, East China (Zhao & Zhang 1986a).

Ganoderma is the largest genus in *Ganodermataceae* including 459 taxa recorded in Index Fungorum (http://www.indexfungorum.org/) as of 17 April 2021. Considering previous studies and the current morphological and phylogenetic analyses, 181 species of *Ganoderma* are confirmed, including 16 new species; 40 species was confirmed for China (Moncalvo & Ryvarden 1997, Ryvarden 2004b, Cao *et al.* 2012, Dai 2012, Hapuarachchi *et al.* 2018b, Xing *et al.* 2018, Hapuarachchi *et al.* 2019b, Decock & Ryvarden 2020, Ryvarden 2020). In this study, 95 taxa of *Ganoderma* with available molecular data were involved in the phylogenetic analyses and divided into 10 clades based on the laccate or dull pileal surface (Fig. 1). The species in subclade I (84 % ML, 1.00 BPP) have laccate pileal surface except *G. mirabile*. Subclade II (100 % ML, 1.00 BPP) and subclade III (100 % ML, 1.00 BPP) constituted monophyletic laccate species. Subclade IV (100 % ML, 1.00 BPP) and subclade VI (98 % ML, 1.00 BPP) were only composed of the species with a dull pileal surface. Subclade V (93 % ML, 1.00 BPP) included the species with dull pileal surface except *G. destructans*, *G. dunense*, *G. mutabile* and *G. pfeifferi* which have visibly obviously laccate pileal surface. Except for *G. hoehnelianum* and *G. puerense sp. nov.*, subclade VII (75 % ML, 0.99 BPP), subclade VIII, subclade IX (100 % ML, 1.00 BPP) and subclade X (99 % ML, 1.00 BPP) were formed by the laccate species. According to the evolutionary progress in the phylogenetic tree, it might be assumed that *Ganoderma* species have evolved from laccate to dull. Whether the feature of laccate or dull pileal surface can be the key evidence for reconstructing classification system of *Ganoderma* remains to be explored in the future.

Fryssouli *et al*. (2020) performed a single-gene phylogenetic analysis for 80 *Ganoderma* species based on ITS sequences, and the *Ganoderma* species were divided into five clades: Clade A (including clusters A1, A2, A3), Clade B, Clade C (including clusters C1, C2), Clade D (including clusters D1, D2, D3, D4), Clade E (including clusters E1, E2, E3, E4, E5). Clade A consisted of both laccate species and dull species, and these species form four different subclades (subclade VII, subclade VIII, subclade IX, subclade X) in our study. Clade B consisted of dull species, which is corresponding to subclade VI composed of the species with dull pileal surface in our study. Clade C includes six species from Paleotropics with laccate pileal surface in corresponding to subclade II in our study. Clade D included four clusters, cluster D1 only include *G. mbrekobenum*, which is corresponding to subclade III in our study, while clusters D2, D3 and D4 all including laccate species which formed subclade I in our study. Clade E (including clusters E1, E2, E3, E4, E5) is consisted of species with both laccate and dull pileal surface, cluster E1 only includes dull species which formed subclade IV in our study, while clusters E2, E3, E4 and E5 including both laccate and dull species which formed subclade V in our study. This indicated that the division of *Ganoderma* species by ITS based analysis by Fryssouli *et al*. (2020) is different from the division of *Ganoderma* species by our multiple gene-based analysis (Fig. 1). Moreover, the ITS based phylogenetic analysis (Fig. 2) for species of *Ganoderma* and related genera in our current study shown that species of *Ganoderma* were mixed together with other genera, which indicated that the single ITS based analysis is not sufficient to investigate the relationship of *Ganoderma* and related genera.

Amauroderma s. str., *Foraminispora*, *Furtadoella* and *Sanguinoderma* were separated from *Amauroderma s. lat.* based on morphological and phylogenetic studies (Costa-Rezende *et al.* 2017, Sun *et al.* 2020). As of 17 April 2021, 137 taxa of *Amauroderma* had been recorded in Index Fungorum (http://www.indexfungorum.org/), among them 58 species were confirmed as independent species (Table 2). According to Costa-Rezende *et al.* (2020a), 24 *Amauroderma* species were reported from the Neotropics, among those 16 species were phylogenetically supported. The previous studies have recorded 24 species of *Amauroderma* in China (Zhao & Zhang 2000, Li & Yuan 2015, Song et al. 2016), however, 16 of them have been demonstrated as synonyms or with confused nomenclatures (Steyaert 1972, Moncalvo & Ryvarden 1997, Li & Yuan 2015, Sun *et al.* 2020), and the others need to be abandoned because of incorrect descriptions or misidentifications; for the time being, there are no species of *Amauroderma s. str.* Known from China. *Foraminispora* was established by Costa-Rezende *et al.* (2017) and typified by *Fo. rugosa* from the Neotropics. Sun *et al.* (2020) proposed that, *Fo. austrosinensis*, *Fo. concentrica*, *Fo. yinggelingensis* and *Fo. yunnanensis* which were described from China should be included in *Foraminispora* based on similar spore ultrastructure characters and phylogenetic analysis. *Furtadoella* consisted of three species from the Neotropics based on soft basidiomata with dull pileal surface and pale context, dimitic hyphal system in trama but a monomitic hyphal system in context, with both clamped and simple-septate generative hyphae (Costa-Rezende *et al.* 2017). *Sanguinoderma* is composed of species from tropical Asia, Africa and Oceania, with the colour of fresh pore surface changing to blood red when bruised. In this study, six new species were described with effective morphological differences

and phylogenetic support, and a total of 16 species were confirmed in *Sanguinoderma*.

Costa-Rezende *et al.* (2020b) established two genera in *Ganodermataceae* with adequate analyses, which was further confirmed in this study. *Amaurodermellus* is proposed to contain the Neotropical species: *Amauroderma ovisporum* based on amaurodermoid basidiomata with ovoid and non-truncated basidiospores. *Cristataspora* is composed of *Ganoderma coffeatum* and *G. flaviporum*, which are distinguished by stipitate basidiomata with white context, and truncated basidiospores with vertical or transverse ridges on the endospore walls. *Ganoderma coffeatum* was recorded by Zhao & Zhang (2000) as *Humphreya coffeata* in China, but the specimens stored in HMAS has been determined as *G. lucidum* through morphological observation.

Haddowia was established by Steyaert (1972) including *Ha. aëtii* and *Ha. longipes* based on non-truncated basidiospores with longitudinal ridges partly connected with short transverse walls on exospore walls (Fig. 8 E). Zmitrovich (2018) combined *Ha. aëtii* to *Ganoderma* as *G. aetii*. In this study, *Ha. macropora* was described from French Guiana as a new species with yellowish brown pileal surface, large pores, intermittently longitudinal crests and transverse membranes on the exospore walls.

Humphreya has unique basidiospores with truncated apex and reticular or erratic irregularly ridged double walls. *Humphreya coffeata* has been combined to *Cristataspora* due to the longitudinally orientated crests as an independent phylogenetic branch (Costa-Rezende *et al.* 2020b). The taxonomic status of *Hu. eminii*, *Hu. endertii* and *Hu. lloydii* need to be further clarified based on more specimens.

In comparison to other genera, *Magoderna* has anticlinal hyphae in the pileipellis, ellipsoid to ovoid basidiospores with faintly verrucose exospore wall and tiny spinules on the endospore wall (Fig. 8 F). *Magoderna infundibuliforme*, *M. subresinosum* and *M. vansteenisii* were first included in *Magonderna* when it was established as a genus (Steyaert 1972). *Magoderna vansteenisii* has since been combined as *Sanguinoderma rugosum* by Corner (1983) without type specimen examination. And no available specimen of *M. infundibuliforme* was examined in this study, so, it should be kept as separate species in *Magoderna* before studying type specimens.

Tomophagus can be distinguished by the pale and soft context, and dimitic hyphal system with branched generative hyphae (Le *et al.* 2012). *Tomophagus colossus* and *To. cattienensis* were included into *Tomophagus* and formed an independent clade with good support in the phylogenetic tree (Fig. 1). One specimen of *To. cattienensis* collected from Malaysia was examined by macro-morphology, and microscopic examinations together with ultrastructural observations. The exospore wall of the basidiospores in *Tomophagus* was slightly foveolate to verrucose to reticulate which resembles *Ganoderma*, but the ornamentation of the latter is deeper (Fig. 8D, I). The detailed descriptions of *Tomophagus* given in this study make it more credible and recognisable as genus in *Ganodermataceae*.

Trachyderma was renamed as *Trachydermella* due to its illegitimacy, and has one species so far, *Tr. tsunodae*. In this study, *Tr. tsunodae* showed to be an independent clade with high support in the phylogenetic tree (Fig. 1). The specimen collected in southwestern China was confirmed by the watery context when fresh and large hyphae, spores and basidia, since no sequence could be generated. The ornamentation of basidiospores in *Trachydermella* has been observed under SEM, and shows a similar verrucose to reticulate exospore wall to that in *Amauroderma* and *Furtadoella*. However, the distinctly truncated apex of the basidiospores distinguishes *Trachydermella* from *Amauroderma* and *Furtadoella* (Fig. 8A, C, J).

After several studies, 642 taxa of *Ganodermataceae* were recorded in Index Fungorum (http://www.indexfungorum.org/) as of 10 March 2022, among which *Amauroderma* which has 141 records, *Amaurodermellus* has one species, *Cristataspora* has two species, *Foraminispora* has five species, *Furtadoella* has three species, *Ganoderma* has 467 records, *Haddowia* has three records, *Humphreya* has four records, *Magoderna* has three records, *Tomophagus* has two species, *Trachydermella* has one species and *Sanguinoderma* has 10 species. According to the nomenclatural study of *Ganodermataceae* by Moncalvo & Ryvarden (1997) and other studies, there are four major reasons to abandon some species: i) they are synonyms of already named species, ii) the type specimens are lost or immature, iii) they represent invalid names, and iv) there are errors in sequencing and nomenclature. Based on these reasons, we have now confirmed 278 species in the world (Table 2), and 145 of them have molecular data.

In the past few decades, many scholars have focused on exploring the diversity of *Ganodermataceae* with 130 taxa of *Ganodermataceae* in China (Zhao & Zhang 2000, Cao & Yuan 2012, Dai 2012, Wang & Wu 2014, Li *et al.* 2015, Zhou *et al.* 2015, Hapuarachchi *et al.* 2018b, Xing *et al.* 2018, Ye *et al.* 2019, Sun *et al.* 2020, He *et al.* 2021). Previously, the mostly recorded species were recognised only based on morphological characters. However in recent years, phylogenetic analyses have applied to the studies of *Ganodermataceae*. As a result of these studies, more than 30 species have been regarded as synonyms, and several taxa should be abandoned due to being immature specimens without basidiospores or confusing original descriptions (Wang 2005, Cao 2013, Li & Yuan 2015, Xing 2019). Sun *et al.* (2020) classified seven species originally reported as *Amauroderma* in China as other species, and Costa-Rezende *et al.* (2020b) combined *Humphreya coffeatum* to *Cristataspora*. In this study, the remnant of the species was checked based on morphological comparisons and geographic distribution together with phylogenetic analyses. For the time being, 59 species of *Ganodermataceae* are recognised in China, of which only one without available sequences. The recorded taxa of *Ganodermataceae* reported in China and its current taxonomic status are presented in Table 3.

Just recently, two additional new species of *Ganoderma*, *G. dianzhongense* and *G. esculentum* were described by He *et al.* (2021), the morphological characters and molecular evidence were sufficient to recognize their legitimacy even if they were not included in our current phylogenetic analyses. Both of them have been listed in Tables 2 and 3 along with other species of *Ganoderma* in China.

Since ITS and nLSU sequences were first used to identify *Ganoderma* species in Moncalvo *et al.* (1995), many DNA sequences have been uploaded to GenBank (https://www.ncbi.nlm.nih.gov/). These sequences are mostly generated from eight genes: ITS, nLSU, *rpb1*, *rpb2*, *tef1*, *tub*, mtSSU and nSSU; *rpb1* and *tub* are not widely for *Ganodermataceae* due to insufficient quantity. To evaluate the practicability and reliability of six genes, the phylogenetic analyses of *Ganodermataceae* based on ITS, nLSU, *rpb2*, *tef1*, mtSSU and nSSU sequences were carried out respectively (Figs 2–7). The internal transcribed spacer region (ITS) was considered as the universal barcode of fungi (Schoch *et al.* 2012), but its limitation in identifying complex groups or potential species cannot be ignored (Badotti *et al.* 2017) even if ITS is the most abundant gene region in *Ganodermataceae*. Loci such as *rpb2* and *tef1* are very useful for identifying the species

Table 3. Taxonomic status of *Ganodermataceae* reported from China.

Genus	Taxa	Current status	References
Amauroderma (24)	*A. amoiense*	= *Sanguinoderma rugosum*	Li & Yuan (2015)
	A. auriscalpium	Nomenclature unclear and holotype sterile	Moncalvo & Ryvarden (1997)
	A. austrosinense	= *Foraminispora austraosinensis*	Sun *et al.* (2020)
	A. bataanense	= *Sanguinoderma bataaense*	Sun *et al.* (2020)
	A. concentricum	= *Foraminispora concentrica*	Sun *et al.* (2020)
	A. conjunctum	Inconsistent with original description	This study
	A. dayaoshanense	= *Pyrrhoderma sendaiense*	Li & Yuan (2015)
	A. elmerianum	= *Sanguinoderma elmerianum*	Sun *et al.* (2020)
	A. exile	Specimens lost and only distributed in Neotropics	This study
	A. fujianense	= *Ganoderma fornicatum*	Li & Yuan (2015)
	A. guangxiense	Type specimen lost	This study
	A. hongkongense	Holotype polluted and sterile	This study
	A. jiangxiense	Ganodermoid basidiocarps and sterile	This study
	A. longgangense	Ganodermoid basidiocarps and sterile	This study
	A. nigrum	Nomenclature unclear	Moncalvo & Ryvarden (1997)
	A. perplexum	= *Sanguinoderma perplexum*	Sun *et al.* (2020)
	A. preussii	= *Sanguinoderma infundibulare sp. nov.*	This study
	A. rude	= *Sanguinoderma rude*	Sun *et al.* (2020)
	A. rugosum	= *Sanguinoderma rugosum*	Sun *et al.* (2020)
	A. schomburgkii	= *Sanguinoderma elmerianum*	This study
	A. sikorae	= *Amauroderma preussii*	Steyaert (1972)
	A. subresinosum	= *Magoderna subresinosum*	Sun *et al.* (2020)
	A. wuzhishanense	= *Amauroderma rugosum*	Li & Yuan (2015)
	A. yunnanense	= *Foraminispora yunnanensis*	Sun *et al.* (2020)
Ganoderma (104)	*G. ahmadii*	√	This study
	G. albomarginatum	Nomenclature repeated with same specimen	Xing (2019)
	G. amboinense	Nomenclature unclear	Moncalvo & Ryvarden (1997)
	G. angustisporum	√	Xing *et al.* (2018)
	G. annulare	= *Ganoderma australe*	Ryvarden (1989)
	G. applanatum	√	Dai (2012)
	G. atrum	= *Ganoderma flexipes*	Cao (2013)
	G. australe	√	Dai (2012)
	G. austrofujianense	= *Ganoderma sinense*	Cao (2013)
	G. bawanglingense	= *Ganoderma australe*	This study
	G. bicharacteristicum	Holotype sterile	Xing (2019)
	G. boninense	√	Wang (2005)
	G. brownii	Inconsistent with original description	Wang (2005)
	G. calidophilum	√	This study
	G. cantharelloideum	= *Ganoderma lucidum*	Cao (2013)
	G. capense	= *Ganoderma weberianum*	Wang (2005)
	G. casuarinicola	√	Xing *et al.* (2018)
	G. chalceum	Inconsistent with original description	This study
	G. chenghaiense	= *Ganoderma multipileum*	Cao (2013)
	G. chiungchungense	Description and type specimen unclear	Xing (2019)
	G. cochlear	Nomenclature unclear and type specimen lost	Moncalvo & Ryvarden (1997)
	G. colossus	= *Tomophagus colossus*	Cao (2013)
	G. crebrostriatum	= *Ganoderma mastoporum*	Cao (2013)
	G. cupulatiprocerum	= *Ganoderma duropora*	Zhao & Zhang 2000
	G. curtisii	Inconsistent with original description	Xing (2019)

Table 3. (Continued).

Genus	Taxa	Current status	References
	G. daiqingshanense	= *Ganoderma multiplicatum*	Cao (2013)
	G. densizonatum	= *Ganoderma orbiforme*	Wang *et al.* (2014)
	G. dianzhongense	√	He *et al.* (2021)
	G. diaoluoshanense	= *Ganoderma mastoporum*	Cao (2013)
	G. dimidiatum	Description and type specimen unclear	This study
	G. donkii	Inconsistent with original description	Moncalvo & Ryvarden (1997)
	G. duropora	Inconsistent with original description	This study
	G. ellipsoideum	√	Hapuarachchi *et al.* (2018b)
	G. esculentum	√	He *et al.* (2021)
	G. flexipes	√	Dai (2012)
	G. formosanum	= *Ganoderma sinense*	Cao (2013)
	G. fornicatum	= *Ganoderma orbiforme*	Wang *et al.* (2014)
	G. fulvellum	= *Fomes fulvellus*	This study
	G. gibbosum	√	Luangharn *et al.* (2020)
	G. guinanense	= *Ganoderma sinense*	Cao (2013)
	G. guizhouense	Description and type specimen unclear	Xing (2019)
	G. hainanense	= *Ganoderma flexipes*	Cao (2013)
	G. hoehnelianum	√	This study
	G. jianfenglingense	Description and type specimen unclear	Xing (2019)
	G. kunmingense	Holotype sterile	Cao (2013)
	G. leucocontextum	√	Li *et al.* (2015)
	G. limushanense	= *Ganoderma orbiforme*	Wang *et al.* (2014)
	G. lingzhi	√	Cao *et al.* (2012)
	G. lobatum	Inconsistent with original description	This study
	G. lucidum	√	This study
	G. luteomarginatum	= *Ganoderma sinense*	Cao (2013)
	G. magniporum	√	This study
	G. mastoporum	= *Ganoderma orbiforme*	Wang *et al.* (2014)
	G. mediosinense	= *Ganoderma sinense*	Cao (2013)
	G. meijiangense	= *Ganoderma williamsianum*	Wang & Wu (2010)
	G. microsporum	= *Ganoderma weberianum*	Cao (2013)
	G. mirabile	Climate different with type locality	This study
	G. mirivelutinum	= *Ganoderma australe*	This study
	G. mongolicum	Unlike *Ganoderma*	Wang (2005)
	G. multipileum	√	Dai (2012)
	G. multiplicatum	Inconsistent with original description	This study
	G. mutabile	√	Cao & Yuan (2012)
	G. neojaponicum	Inconsistent with original description	Wang (2005)
	G. nigrolucidum	Inconsistent with original description	Wang (2005)
	G. nitidum	Climate different with type locality	This study
	G. ochrolaccatum	Inconsistent with original description	This study
	G. orbiforme	√	Wang *et al.* (2014)
	G. ostracodes	Inconsistent with original description	Wang (2005)
	G. parviungulatum	= *Ganoderma flexipes*	Cao (2013)
	G. petchii	Inconsistent with original description	This study
	G. pfeifferi	Inconsistent with original description	Wang (2005)
	G. philippii	√	Dai (2012)
	G. ramosissimum	Holotype sterile	Cao (2013)
	G. renii	Description unclear and type specimen lost	Cao (2013)

Table 3. (Continued).

Genus	Taxa	Current status	References
	G. resinaceum	Inconsistent with original description	Xing (2019)
	G. rotundatum	= *Ganoderma multiplicatum*	Cao (2013)
	G. sanduense	√	Hapuarachchi *et al.* (2019b)
	G. sanmingense	Holotype sterile	Cao (2013)
	G. shandongense	= *Sinoganoderma shandongense comb. nov.*	This study
	G. shangsiense	= *Ganoderma hoehnelianum*	Wang & Wu (2010)
	G. shanxiense	√	Liu *et al.* (2019)
	G. sichuanense	√	Wang *et al.* (2012)
	G. simaoense	Holotype sterile	Cao (2013)
	G. sinense	√	Dai (2012)
	G. stipitatum	= *Ganoderma tropicum*	Wang (2005)
	G. stratoideum	Description unclear and type specimen lost	Xing (2019)
	G. subumbraculum	= *Ganoderma weberianum*	Wang (2005)
	G. tenue	= *Ganoderma weberianum*	Cao (2013)
	G. theaecola	= *Ganoderma multiplicatum*	Cao (2013)
	G. tibetanum	Description and type specimen unclear	Xing (2019)
	G. triangulum	= *Ganoderma australe*	This study
	G. tropicum	√	Dai (2012)
	G. trulla	Inconsistent with original description	This study
	G. tsugae	√	Dai (2012)
	G. tsunodae	= *Trachydermella tsunodae comb. nov.*	This study
	G. ungulatum	= *Ganoderma australe*	This study
	G. valesiacum	Inconsistent with original description	Wang (2005)
	G. weberianum	√	Dai (2012)
	G. weixiense	√	Ye *et al.* (2019)
	G. williamsianum	√	Dai (2012)
	G. wuhuense	Description unclear and type specimen lost	Xing (2019)
	G. wuzhishanense	Molecular sequence error	Xing (2019)
	G. xingyiense	Description unclear and type specimen lost	Xing (2019)
	G. zhenningense	Description and type specimen unclear	Xing (2019)
Haddowia (1)	*Ha. longipes*	√	Dai (2012)
Humphreya (1)	*Hu. coffeatum*	Inconsistent with original description	This study

in *Ganodermataceae*, but the instability of them usually produces uncontrollable mutations. Compared to other genes, nLSU, mtSSU and nSSU are so conservative that it is hard to delimit the species in *Ganodermataceae* using just these genes. Thus, phylogenetic analyses based on a gene locus alone is insufficient and a combined multi-gene dataset with ITS, nLSU, *rpb2*, *tef1*, *rpb1* and *tub*, is better recommended for phylogenetic analyses of *Ganodermataceae*. In this study, 1 382 sequences from 391 specimens were used in the phylogenetic analyses which included 63 type specimens. There were 817 sequences newly generated and uploaded to GenBank, including 132 sequences of ITS, 139 sequences of nLSU, 83 sequences of *rpb2*, 124 sequences of *tef1*, 150 sequences of mtSSU and 189 sequences of nSSU. The reliability of these sequences was referenced by literature citations, released information on NCBI and practical application, which suggests that the sequences used in this study should be the basis of future phylogenetic analyses of *Ganodermataceae*.

ACKNOWLEDGEMENTS

We express our gratitude to Prof Yu-Cheng Dai (China) for providing specimens and pictures for our study. The curators of herbaria of HMAS, HKAS, GDGM, IFP and Drs Tom May (Australia), Hai-Jiao Li (China), Jie Song (China), Lu-Lu Shen (China), Mei-Ling Han (China), Jun-Liang Zhou (China) and Ms. Xing Ji (China), Yan Wang (China), Yu-Li Han (China) are thanked for help during field collections and molecular studies. Drs Shuang-Hui He (China), Fang Wu (China), Hai-Sheng Yuan (China), Yu-Lian Wei (China), Li-Wei Zhou (China), Jun-Zhi Qiu (China), Hai-Xia Ma (China), Bo Zhang (China), Shi-Liang Liu (China), Ming Zhang (China), De-Wei Li (USA) are thanked for companionship during field collections. Dr Sheng-Hua Wu (China) is thanked for providing valuable suggestions on this study. The research was supported by the National Natural Science Foundation of China (Nos. U2003211, 31870008, 31670016), the Scientific and Technological Tackling Plan for the Key Fields of Xinjiang Production and Construction Corps (No. 2021AB004) and Beijing Forestry University Outstanding Young Talent Cultivation Project (No. 2019JQ03016).

DECLARATION ON CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

REFERENCES

Adaskaveg JE, Gilbertson RL (1986). Cultural studies and genetics of sexuality of *Ganoderma lucidum* and *G. tsugae* in relation to the taxonomy of the *G. lucidum* complex. *Mycologia* **78**: 694–705.

Aime MC, Henkel TW, Ryvarden L (2003). Studies in Neotropical polypores 15: New and interesting species from Guyana. *Mycologia* **95**: 614–619.

Aime L, Ryvarden L, Henkel TW (2007). Studies in Neotropical polypores 22. Additional new and rare species from Guyana. *Synopsis Fungorum* **23**: 15–31.

Ainsworth GC, Bisby GR (1971). *Dictionary of the fungi*. Commonwealth Mycological Institute, UK.

Badotti F, de Oliveira FS, Garcia CF, *et al.* (2017). Effectiveness of ITS and sub-regions as DNA barcode markers for the identification of *Basidiomycota* (Fungi). *BMC Microbiology* **17**: 1–42.

Binder M, Justo A, Riley R, *et al.* (2013). Phylogenetic and phylogenomic overview of the *Polyporales*. *Mycologia* **105**: 1350–1373.

Boddy L, Büntgen U, Egli S, *et al.* (2014). Climate variation effects on fungal fruiting. *Fungal Ecology* **10**: 20–33.

Bolaños AC, Bononi VLR, de Mello Gugliotta A, *et al.* (2016). New records of *Ganoderma multiplicatum* (Mont.) Pat. (*Polyporales*, *Basidiomycota*) from Colombia and its geographic distribution in South America. *Check List* **12**: 1–7.

Bresadola G (1912). *Polyporaceae* Javanicae. *Annales Mycologici* **10**: 492–508.

Bresadola G (1915). *Basidiomycetes* Philippinenses. Series III. *Hedwigia* **56**: 289–307.

Cabarroi-Hernández M, Villalobos-Arámbula AR, Torres-Torres MG, *et al.* (2019). The *Ganoderma weberianum-resinaceum* lineage: multilocus phylogenetic analysis and morphology confirm *G. mexicanum* and *G. parvulum* in the neotropics. *MycoKeys* **59**: 95–131.

Campacci TVS, Gugliotta AM (2009). A review of *Amauroderma* in Brazil, with the new record of *A. oblongisporum* in the Neotropics. *Mycotaxon* **110**: 423–436.

Cao Y (2013). *Taxonomy and phylogeny of Ganoderma in China*. Ph.D. dissertation. The University of Chinese Academy of Sciences in Shenyang, China.

Cao Y, Yuan HS (2012). *Ganoderma mutabile sp. nov.* from southwestern China based on morphological and molecular data. *Mycological Progress* **12**: 121–126.

Cao Y, Wu SH, Dai YC (2012). Species clarification of the prize medicinal *Ganoderma* mushroom 'Lingzhi'. *Fungal Diversity* **56**: 49–62.

Chan PM, Kanagasabapathy G, Tan YS, *et al.* (2013). *Amauroderma rugosum* (Blume & T. Nees) Torrend: nutritional composition and antioxidant and potential anti-inflammatory properties. *Evidence-Based Complementary and Alternative Medicine* **2013**: 1–10.

Coelho G, Cortez VG, Guerrero RT (2007). New morphological data on *Amauroderma brasiliense* (Polyporales, Basidiomycota). *Mycotaxon* **2007**: 177–183.

Coetzee MPA, Marincowitz S, Muthelo VG, *et al.* (2015). *Ganoderma* species, including new taxa associated with root rot of the iconic *Jacaranda mimosifolia* in Pretoria, South Africa. *IMA Fungus* **6**: 249–256.

Corner EJH (1983). Ad Polyporaceas I. *Amauroderma* and *Ganoderma*. *Beihefte zur Nova Hedwigia* **75**: 1–182.

Costa-Rezende DH, Gugliotta AM, Góes-Neto A, *et al.* (2016). *Amauroderma calcitum sp. nov.* and notes on taxonomy and distribution of *Amauroderma* species (*Ganodermataceae*). *Phytotaxa* **244**: 101–124.

Costa-Rezende DH, Robledo GL, Góes-Neto A, *et al.* (2017). Morphological reassessment and molecular phylogenetic analyses of *Amauroderma s. lat.* raised new perspectives in the generic classification of the *Ganodermataceae* family. *Persoonia* **39**: 254–269.

Costa-Rezende DH, Góes-Neto A, Drechsler-Santos ER (2020a). Studies on Brazilian *Amauroderma s. str.* reveal a new species from the Atlantic forest, *Amauroderma robledoi sp. nov.* (*Polyporales*, *Ganodermataceae*). *The Journal of the Torrey Botanical Society* **147**: 199–205.

Costa-Rezende DH, Robledo GL, Drechsler-Santos ER, *et al.* (2020b). Taxonomy and phylogeny of polypores with ganodermatoid basidiospores (*Ganodermataceae*). *Mycological Progress* **19**: 725–741.

Crous PW, Wingfield MJ, Schumacher RK, *et al.* (2014). Fungal Planet Description Sheets: 281–319. *Persoonia* **33**: 212–289.

Crous PW, Wingfield MJ, Le Roux, *et al.* (2015). Fungal Planet Description Sheets: 371–399. *Persoonia* **35**: 264–327.

Crous PW, Wingfield MJ, Richardson DM, *et al.* (2016). Fungal Planet description sheets: 400–468. *Persoonia* **36**: 316–458.

Crous PW, Wingfield MJ, Burgess TI, *et al.* (2017a). Fungal Planet description sheets: 558–624. *Persoonia* **38**: 240–384.

Crous PW, Wingfield MJ, Burgess TI, *et al.* (2017b). Fungal Planet description sheets: 625–715. *Persoonia* **39**: 270–467.

Crous PW, Luangsa-ard JJ, Wingfield MJ, *et al.* (2018). Fungal Planet Description Sheets: 785–867. *Persoonia* **41**: 238–417.

Cui BK, Li HJ, Ji X, *et al.* (2019). Species diversity, taxonomy and phylogeny of *Polyporaceae* (*Basidiomycota*) in China. *Fungal Diversity* **97**: 137–392.

Dai YC (2012). Polypore diversity in China with an annotated checklist of Chinese polypores. *Mycoscience* **53**: 49–80.

Dai YC, Yang ZL, Cui BK, *et al.* (2009). Species diversity and utilization of medicinal mushrooms and fungi in China. *International Journal of Medicinal Mushrooms* **11**: 287–302.

De Lima Júnior N, Gibertoni BT, Malosso E (2014). Delimitation of some Neotropical laccate *Ganoderma* (*Ganodermataceae*): molecular phylogeny and morphology. *Revista de Biologia Tropical* **62**: 1197–1208.

Decock C, Ryvarden L (2020). *Aphyllophorales* of Africa 41. Some polypores from Gabon. *Synopsis Fungorum* **42**: 5–15.

Donk MA (1948). Notes on Malesian fungi. I. *Bulletin du Jardin Botanique de Buitenzorg* **17**: 473–482.

Douanla-Meli C, Langer E (2009). *Ganoderma carocalcareus sp. nov.*, with crumbly-friable context parasite to saprobe on *Anthocleista nobilis* and its phylogenetic relationship in *G. resinaceum* group. *Mycological Progress* **8**: 145–155.

Farris JS, Kallersjo M, Kluge AG, *et al.* (1994). Testing significance of incongruence. *Cladistics* **10**: 315–319.

Foroutan A, Vaidya JG (2007). Record of new species of *Ganoderma* in Maharashtra, India. *Asian Journal of Plant Sciences* **6**: 913–919.

Fryssouli V, Zervakis GI, Polemis E, *et al.* (2020). A global meta-analysis of ITS rDNA sequences from material belonging to the genus *Ganoderma* (*Basidiomycota*, *Polyporales*) including new data from selected taxa. *MycoKeys* **75**: 71–143.

Furtado JS (1967a). Some tropical species of *Ganoderma* (*Polyporaceae*) with pale context. *Persoonia* **4**: 379–389.

Furtado JS (1967b). Species of *Amauroderma* Murr. with the laccate appearance of *Ganoderma* Karst. *Bulletin du Jardin Botanique National de Belgique* **37**: 309–317.

Gibertoni T, Bernicchia A, Ryvarden L, *et al.* (2008). Bresadola's polypore collection at the Natural History Museum of Trento, Italy 2. *Mycotaxon* **104**: 321–323.

Glen M, Bougher NL, Francis AA, *et al.* (2009). *Ganoderma* and *Amauroderma* species associated with root-rot disease of *Acacia mangium* plantation trees in Indonesia and Malaysia. *Australasian Plant Pathology* **38**: 345–356.

Gomes-Silva AC, Baltazar JM, Ryvarden L, *et al.* (2010). *Amauroderma calcigenum* (*Ganodermataceae*, *Basidiomycota*) and its presumed synonym *A. partitum*. *Nova Hedwigia* **90**: 449–455.

Gomes-Silva AC, Gibertoni TB (2012). Neotypification of *Amauroderma picipes* Torrend, 1920 (*Ganodermataceae*, *Agaricomycetes*). *Mycosphere* **3**: 23–27.

Gomes-Silva AC, De Lima-Júnior NC, Malosso E, *et al.* (2015). Delimitation of taxa in *Amauroderma* (*Ganodermataceae*, *Polyporales*) based

in morphology and molecular phylogeny of Brazilian specimens. *Phytotaxa* **227**: 201–228.
Gottlieb AM, Ferrer E, Wright JE (2000). rDNA analyses as an aid to the taxonomy of species of *Ganoderma*. *Mycological Research* **104**: 1033–1045.
Gulaid H, Ryvarden L (1998). Two new species of *Amauroderma* (*Ganodermataceae*, *Basidiomycetes*). *Mycologia Helvetica* **10**: 25–30.
Hall TA (1999). Bioedit: a user-friendly biological sequence alignment editor and analysis program for Windows 95/98/NT. *Nucleic Acids Symposium Series* **41**: 95–98.
Hapuarachchi KK, Karunarathna SC, Phengsintham P, *et al.* (2018a). *Amauroderma* (*Ganodermataceae*, *Polyporales*) – bioactive compounds, beneficial properties and two new records from Laos. *Asian Journal of Mycology* **1**: 121–136.
Hapuarachchi KK, Karunarathna SC, Raspé O, *et al.* (2018b). High diversity of *Ganoderma* and *Amauroderma* (*Ganodermataceae*, *Polyporales*) in Hainan Island, China. *Mycosphere* **9**: 931–982.
Hapuarachchi KK, Karunarathna SC, McKenzie EHC, *et al.* (2019a). High phenotypic plasticity of *Ganoderma sinense* (*Ganodermataceae*, *Polyporales*) in China. *Asian Journal of Mycology* **2**: 1–47.
Hapuarachchi KK, Karunarathna SC, Phengsintham P, *et al.* (2019b). *Ganodermataceae* (*Polyporales*): diversity in greater Mekong subregion countries (China, Laos, Myanmar, Thailand and Vietnam). *Mycosphere* **10**: 221–309.
He J, Luo ZL, Tang SM, *et al.* (2021). Phylogenetic analyses and morphological characters reveal two new species of *Ganoderma* from Yunnan Province, China. *MycoKeys* **84**: 141–162.
He SC, Yu HF (1989). The family *Ganodermataceae* from Guizhou Province of China II. *Acta Mycologica Sinica* **8**: 282–288.
Henao-M LG (1997). Afiloforales de Colombia III: *Amauroderma* (*Basidiomycetes*: *Ganodermataceae*) en el Herbario Nacional Colombiano. *Caldasia* **19**: 131–143.
Humphrey CJ (1938). Notes on some *Basidiomycetes* from the Orient. *Mycologia* **30**: 327–335.
Imazeki R (1952). A contribution to the fungus flora of Dutch New Guinea. *Bulletin of the Government Forest Experimental Station Meguro* **57**: 87–128.
Ipulet P, Ryvarden L (2005). New and interesting polypores from Uganda. *Synopsis Fungorum* **20**: 87–99.
Jong WYL, Show PL, Ling TC, *et al.* (2017). Recovery of lignin peroxidase from submerged liquid fermentation of *Amauroderma rugosum* (Blume & T. Nees) Torrend using polyethylene glycol/salt aqueous two-phase system. *Journal of Bioscience and Bioengineering* **124**: 91–98.
Justo A, Miettinen O, Floudas D, *et al.* (2017). A revised family-level classification of the *Polyporales* (*Basidiomycota*). *Fungal Biology* **121**: 798–824.
Katoh K, Standley DM (2013). MAFFT Multiple sequence alignment software version 7: improvements in performance and usability. *Molecular Biology Evolution* **30**: 772–780.
Kim HK, Seo GS, Kim HG (2001). Comparison of characteristics of *Ganoderma lucidum* according to geographical origins: consideration of morphological characteristics (II). *Mycobiology* **29**: 80–84.
Kinge TR, Mih AM (2011). *Ganoderma ryvardense sp. nov.* associated with basal stem rot (BSR) disease of oil palm in Cameroon. *Mycosphere* **2**: 179–188.
Kinge TR, Mih AM (2014). *Ganoderma lobenense* (*Basidiomycetes*), a new species from oil palm (*Elaeis guineensis*) in Cameroon. *Journal of Plant Sciences* **2**: 242–245.
Le XT, Le QHN, Pham ND, *et al.* (2012). *Tomophagus cattienensis sp. nov.*, a new *Ganodermataceae* species from Vietnam: evidence from morphology and ITS DNA barcodes. *Mycological Progress* **11**: 775–780.
Le XT, Le QHN, Bui HT, *et al.* (2018). Current status of *Humphreya endertii* and a new species (*Ganodermataceae*) recorded in South Vietnam. *Agrica* **7**: 102–109.
Li MJ, Yuan HS (2015). Type studies on *Amauroderma* species described by J.D. Zhao *et al.* and the phylogeny of species in China. *Mycotaxon* **130**: 79–89.
Li TH, Hu HP, Deng WQ, *et al.* (2015). *Ganoderma leucocontextum*, a new member of the *G. lucidum* complex from southwestern China. *Mycoscience* **56**: 81–85.
Liao B, Chen XC, Han JP, *et al.* (2015). Identification of commercial *Ganoderma* (Lingzhi) species by ITS2 sequences. *Chinese Medicine* **10**: 22.
Liu H, Guo LJ, Li SL, *et al.* (2019). *Ganoderma shanxiense*, a new species from northern China based on morphological and molecular evidence. *Phytotaxa* **406**: 129–136.
Liu YJ, Whelen S, Hall BD (1999). Phylogenetic relationships among ascomycetes: evidence from an RNA polymerase II subunit. *Molecular Biology Evolution* **16**: 1799–1808.
Loyd AL, Held BW, Barnes CW, *et al.* (2018). Elucidating '*lucidum*': distinguishing the diverse laccate *Ganoderma* species of the United States. *PLoS ONE* **13**: e0199738.
Luangharn T, Karunarathna SC, Mortimer PE, *et al.* (2019). Additions to the knowledge of *Ganoderma* in Thailand: *Ganoderma casuarinicola*, a new record; and *Ganoderma thailandicum sp. nov. MycoKeys* **59**: 47–65.
Luangharn T, Karunarathna SC, Mortimer PE, *et al.* (2020). Morphology, phylogeny and culture characteristics of *Ganoderma gibbosum* collected from Kunming, Yunnan Province, China. *Phyton-International Journal of Experimental Botany* **89**: 743–764.
Luangharn T, Karunarathna SC, Dutta AK, *et al.* (2021). *Ganoderma* (*Ganodermataceae*, *Basidiomycota*) species from the greater Mekong subregion. *Journal of Fungi* **7**: 819.
Maddison WP, Maddison DR (2017). *Mesquite: a modular system for evolutionary analysis.* Version 3.2. http://mesquiteproject.org.
Moncalvo JM, Wang HF, Hseu RS (1995). Phylogenetic relationships in *Ganoderma* inferred from the internal transcribed spacers and 25S ribosomal DNA sequences. *Mycologia* **87**: 223–1238.
Moncalvo JM, Ryvarden LA (1997). Nomenclatural study of the *Ganodermataceae* Donk. *Synopsis Fungorum* **11**: 1–114.
Murrill WA (1902). The *Polyporaceae* of North America: I. The genus *Ganoderma*. *Bulletin of the Torrey Botanical Club* **29**: 599–608.
Murrill WA (1905). *Tomophagus* for *Dendrophagus*. *Torreya* **5**: 197.
Murrill WA (1907). Some Philippine *Polyporaceae*. *Bulletin of the Torrey Botanical Club* **34**: 465–481.
Murrill WA (1908a). Additional Philippine *Polyporaceae*. *Bulletin of the Torrey Botanical Club* **35**: 391–416.
Murrill WA (1908b). *Polyporaceae*, Part 2. *North American Flora* **9**: 73–131.
Náplavová K, Beck T, Pristaš P, *et al.* (2020). Molecular data reveal unrecognized diversity in the European *Ganoderma resinaceum*. *Forests* **11**: 850–864.
Nylander JAA (2004). *MrModeltest v2.* Evolutionary Biology Centre, Uppsala University, Program distributed by the author.
Otieno NC (1968). *Polyporaceae* of eastern Africa: II. The genus *Amauroderma* Murrill. *Sydowia* **22**: 173–178.
Papp V (2016). The first validly published laccate *Ganoderma* species from East-Asia: *G. dimidiatum comb. nov.*, the correct name for *G. japonicum*. *Studia Botanica Hungarica* **47**: 263–268.
Patouillard NT (1887). *Les hyménomycètes d'Europe*. Paris.
Patouillard NT (1889). Le genre *Ganoderma*. *Bulletin de la Société Mycologique de France* **5**: 64–80.
Patouillard NT (1907). Champignons nouveaux du Tonkin. *Bulletin de la Société Mycologique de France* **23**: 69–79.
Patouillard NT (1914). Quelques Champignons du Congo. *Bulletin de la Société Mycologique de France* **30**: 336–346.
Petersen JH (1996). *Farvekort. The Danish Mycological Society's colour-chart*. Foreningen til Svampekundskabens Fremme. Greve.
Pilotti CA (2005). Stem rots of oil palm caused by *Ganoderma boninense*: pathogen biology and epidemiology. *Mycopathologia* **159**: 129–137.
Rehner SA, Buckley E (2005). A *Beauveria* phylogeny inferred from nuclear ITS and EF1-α sequences: evidence for cryptic diversification and links to *Cordyceps teleomorphs*. *Mycologia* **97**: 84–98.
Robledo GL, Newman DS, Popoff OF, *et al.* (2015). *Amauroderma trichodermatum* (*Ganodermataceae*, *Basidiomycota*): first record from Bolivia and geographic distribution map, with notes on nomenclature and morphology. *Check List* **11**: 1–5.

Ronquist F, Huelsenbeck JP (2003). MrBayes 3: bayesian phylogenetic inference under mixed models. *Bioinformatics* **19**: 1572–1574.

Ryvarden L (1974). Type studies in the *Polyporaceae* 2. Species described by M. Beeli. *Bulletin du Jardin Botanique National de Belgique* **44**: 65–76.

Ryvarden L (1981). Type studies in the *Polyporaceae* 12. Species described by F. W. Junghuhn. *Persoonia* **11**: 369–372.

Ryvarden L (1983). Type studies in the *Polyporaceae* 14. Species described by N. Patouillard, either alone or with other mycologists. *Occasional Papers of the Farlow Herbarium of Cryptogamic Botany* **18**: 1–39.

Ryvarden L (1989) Type studies in the *Polyporaceae* 21. Species described by C.G. Lloyd in *Cyclomyces*, *Daedalea*, *Favolus*, *Fomes*, and *Hexagonia*. *Mycotaxon* **35**: 229–236.

Ryvarden L (2000). Studies in neotropical polypores 2. A preliminary key to neotropical species of *Ganoderma* with a laccate pileus. *Mycologia* **92**: 180–191.

Ryvarden L (2004a). Studies in neotropical polypores 19. Two wood-inhabiting *Amauroderma* species. *Synopsis Fungorum* **18**: 57–61.

Ryvarden L (2004b). Neotropical polypores. Part 1. Introduction, *Hymenochaetaceae* and *Ganodermataceae*. *Synopsis Fungorum* **19**: 1–227.

Ryvarden L (2015). Type studies in *Polyporaceae* 31. Species described by V. Cesati. *Synopsis Fungorum* **33**: 5–8.

Ryvarden L (2018). Studies in African *Aphyllophorales* 25. New poroid species from East and Central Africa. *Synopsis Fungorum* **38**: 25–32.

Ryvarden L (2020). A new African *Ganoderma* species. *Synopsis Fungorum* **41**: 1–49.

Ryvarden L, Johansen I (1980). *A preliminary polypores flora of East Africa*. Fungiflora, Oslo: 1–636.

Schoch CL, Seifert KA, Huhndorf S, *et al.* (2012). Nuclear ribosomal internal transcribed spacer (ITS) region as a universal DNA barcode marker for fungi. *Proceedings of the National Academy of Sciences of the United States of America* **109**: 6241–6246.

Shen LL, Wang M, Zhou JL, *et al.* (2019). Taxonomy and phylogeny of *Postia*. Multi-gene phylogeny and taxonomy of the brown-rot fungi: *Postia* (*Polyporales*, *Basidiomycota*) and related genera. *Persoonia* **42**: 101–126.

Smith BJ, Sivasithamparam K (2003). Morphological studies of *Ganoderma* (*Ganodermataceae*) from the Australasian and Pacific regions. *Australian Systematic Botany* **16**: 487–503.

Song J, Cui BK (2017). Phylogeny, divergence time and historical biogeography of *Laetiporus* (*Basidiomycota*, *Polyporales*). *BMC Evolutionary Biology* **17**: 102.

Song J, Xing JH, Decock C, *et al.* (2016). Molecular phylogeny and morphology reveal a new species of *Amauroderma* (*Basidiomycota*) from China. *Phytotaxa* **260**: 47–56.

Sotome K, Hattori T, Ota Y (2011). Taxonomic study on a threatened polypore, *Polyporus pseudobetulinus*, and a morphologically similar species, *P. subvarius*. *Mycoscience* **52**: 319–326.

Stamatakis A (2014). RAxML Version 8: a tool for phylogenetic analyses and post analyses of large phylogenies. *Bioinformatics* **30**: 1312–1313.

Steyaert RL (1961). Genus *Ganoderma* (*Polyporaceae*). Taxa nova-I. *Bulletin du Jardin Botanique de l'État à Bruxelles* **31**: 69–83.

Steyaert RL (1967). Les *Ganoderma* palmicoles. *Bulletin Du Jardin Botanique National de Belgique* **37**: 465–492.

Steyaert RL (1972). Species of *Ganoderma* and related genera mainly of the Bogor and Leiden Herbaria. *Persoonia* **7**: 55–118.

Steyaert RL (1980). Study of Some *Ganoderma* Species. *Bulletin Du Jardin Botanique National de Belgique* **50**: 135–186.

Sun YF, Costa-Rezende DH, Xing JH, *et al.* (2020). Multi-gene phylogeny and taxonomy of *Amauroderma s. lat.* (*Ganodermataceae*). *Persoonia* **44**: 206–239.

Swofford DL (2002). *PAUP*: phylogenetic analysis using parsimony (*and other methods), version 4.0b10*. Sinauer Associates, Sunderland.

Tchotet Tchoumi JM, Coetzee MPA, Rajchenberg M, *et al.* (2019). Taxonomy and species diversity of *Ganoderma* species in the Garden Route National Park of South Africa inferred from morphology and multilocus phylogenies. *Mycologia* **111**: 730–747.

Tchotet Tchoumi JM, Coetzee MPA, Rajchenberg M, *et al.* (2018). Three *Ganoderma* species, including *Ganoderma dunense sp. nov.*, associated with dying *Acacia cyclops* trees in South Africa. *Australasian Plant Pathology* **47**: 431–447.

Teixeira AR (1992). New combinations and new names in the *Polyporaceae*. *Revista Brasileira de Botânica* **15**: 125–127.

Teng SC (1963). *Fungi of China*. Beijing Science Press, China.

Torrend C (1920). Les polyporacées du Brésil 1. Polyporacées stipités. *Brotéria Série Botânica* **18**: 121–143.

Torres-Torres MG, Guzmán-Dávalos L (2012). The morphology of *Ganoderma* species with a laccate surface. *Mycotaxon* **119**: 201–216.

Torres-Torres MG, Guzmán-Dávalos L, De Mello AG (2008). *Ganoderma vivianimercedianum sp. nov.* and the related species, *G. perzonatum*. *Mycotaxon* **105**: 447–454.

Vilgalys R, Hester M (1990). Rapid genetic identification and mapping of enzymatically amplified ribosomal DNA from several *Cryptococcus* species. *Journal of Bacteriology* **172**: 4238–4246.

Wang DM (2005). *Phylogenetic study of Ganoderma in China*. Ph.D. dissertation. The University of Chinese Academy of Sciences in Beijing, China.

Wang DM, Wu SH (2010). *Ganoderma hoehnelianum* has priority over *G. shangsiense*, and *G. williamsianum* over *G. meijiangense*. *Mycotaxon* **113**: 343–349.

Wang DM, Wu SH (2014). Two species of *Ganoderma* new to Taiwan. *Mycotaxon* **102**: 373–378.

Wang DM, Yao YJ (2005). Intrastrain internal transcribed spacer heterogeneity in *Ganoderma* species. *Canadian Journal of Microbiology* **51**: 113–121.

Wang DM, Wu SH, Su CH, *et al.* (2009). *Ganoderma multipileum*, the correct name for '*G. lucidum*' in tropical Asia. *Botanical Studies* **50**: 451–458.

Wang DM, Wu SH, Yao YJ (2014). Clarification of the concept of *Ganoderma orbiforme* with high morphological plasticity. *PLoS ONE* **9**: e98733.

Wang H, Deng W, Shen MH, *et al.* (2021). A laccase Gl-LAC-4 purified from white-rot fungus *Ganoderma lucidum* had a strong ability to degrade and detoxify the alkylphenol pollutants 4-n-octylphenol and 2-phenylphenol. *Journal of Hazardous Materials* **408**: 1–16.

Wang XC, Xi RJ, Li Y, *et al.* (2012). The species identity of the widely cultivated *Ganoderma*, "*G. lucidum*" (Ling-Zhi), in China. *PLoS ONE* **7**: e40857.

Welti S, Courtecuisse R (2010). The *Ganodermataceae* in the French West Indies (Guadeloupe and Martinique). *Fungal Diversity* **43**: 103–126.

White TJ, Bruns T, Lee S, *et al.* (1990). Amplification and direct sequencing of fungal ribosomal RNA genes for phylogenetics. In: Innis MA, Gelfand DH, Sninsky JJ, *et al.* (eds) *PCR protocols: a guide to methods and applications*. Academic Press, San Diego: 315–322.

Xing JH (2019). *Species diversity, taxonomy and phylogeny of Ganoderma*. Ph.D. dissertation. Beijing Forestry University, China.

Xing JH, Song J, Decock C, *et al.* (2016). Morphological characters and phylogenetic analysis reveal a new species within the *Ganoderma lucidum* complex from South Africa. *Phytotaxa* **266**: 115–124.

Xing JH, Sun YF, Han YL, *et al.* (2018). Morphological and molecular identification of two new *Ganoderma* species on *Casuarina equisetifolia* from China. *MycoKeys* **34**: 93–108.

Ye L, Karunarathna SC, Mortimer PE, *et al.* (2019). *Ganoderma weixiensis* (*Polyporaceae*, *Basidiomycota*), a new member of the *G. lucidum* complex from Yunnan Province, China. *Phytotaxa* **423**: 75–86.

Zhang XQ (1994). One new species and one new record of *Ganoderma* from China (*Aphyllophorales*, *Basidiomycota*). *Mycosystema* **7**: 105–110.

Zhang Y, Jiang Y, Zhang M, *et al.* (2019). *Ganoderma sinense* polysaccharide: An adjunctive drug used for cancer treatment. *Progress in Molecular Biology and Translational Science* **163**: 165–177.

Zhao CL, Cui BK (2013). Morphological and molecular identification of four new resupinate species of *Perenniporia* (*Polyporales*) from southern China. *Mycologia* **105**: 945–958.

Zhao JD (1989a) Studies on the taxonomy of *Ganodermataceae* in China. XI. Subgen. *Ganoderma* Sect. *Ganoderma*. *Acta Mycologica Sinica* **8**: 25–34.

Zhao JD (1989b). The *Ganodermataceae* in China. *Bibliotheca Mycologica* **132**: 1–176.

Zhao JD, Zhang XQ (1986a). Taxonomic studies on *Ganodermataceae* of China V. *Acta Mycologica Sinica* **5**: 219–225.

Zhao JD, Zhang XQ (1986b). Taxonomic studies on *Ganodermataceae* of China VII – the genus *Amauroderma*. *Acta Mycologica Sinica, Supplement* **1**: 258–272.

Zhao JD, Zhang XQ (2000). *Chinese Fungi No.1 vol. 18. Ganodermataceae*. Beijing Science Press, China.

Zhao JD, Xu LW, Zhang XQ (1979). Taxonomic studies on the subfamily *Ganodermoideae* of China. *Acta Microbiologica Sinica* **19**: 265–279.

Zhao JD, Xu LW, Zhang XQ (1983). Taxonomic studies on *Ganodermataceae* of China II. *Acta Mycologica Sinica* **2**: 159–167.

Zhao JD, Zhang XQ, Xu LW (1984). Studies on the taxonomy of *Ganodermataceae* in China III. *Acta Mycologica Sinica* **3**: 15–23.

Zhou LW, Cao Y, Wu SH, *et al.* (2015). Global diversity of the *Ganoderma lucidum* complex (*Ganodermataceae*, *Polyporales*) inferred from morphology and multilocus phylogeny. *Phytochemistry* **114**: 7–15

Zmitrovich IV (2018). Conspectus systematis Polyporacearum v. 1.0. *Folia Cryptogamica Petropolitana* **6**: 68.